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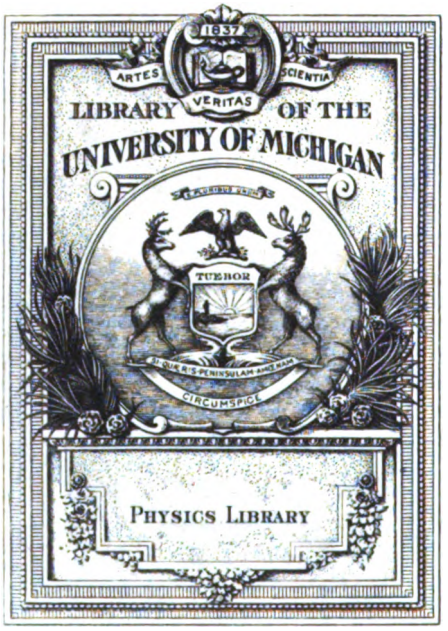

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R380	How to Use up Old Gramophone Records, by H. A. Gaydon, A.M.I.E.E., A.F.Ae.Inst.	Nov., 1924	87
R380·009	A Good Grid Leak and Some Other Components. (Radio Improvements, now Bretwoods)	Feb., 1925	282
R381	The Remote Control of Variable Condensers, by Leonard A. Sayce, M.Sc., A.I.C.	Oct., 1924	9
R381·009	Some Fixed Condensers	Mar., 1925	369
R381·3·009	The R.I. Variable Condenser	Sept., 1925	749
R382	Short Circuited Turns as an Aid to Reception on Short Waves, by W. E. Benham	Dec., 1924	137
R382	The Design of Inductance Coils having a Rectangular Winding Section, by S. Butterworth, M.Sc.	Sept., 1925	750
R382·1	Losses in Inductance Coils at Radio-Frequencies, by Raymond M. Wilmotte, B.A.	May, 1925	477
R382·1	Parasitic Loss in Inductance Coils: A Further Note, by Raymond M. Wilmotte, B.A.	June, 1925	541

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R382·1	The High-Frequency Copper Losses in Inductance Coils, by S. Butterworth, M.Sc.	July, 1925	613
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R382·2·009	The "R.I." Tuner	Oct., 1925	827
R382·5·009	The Sterling Anode Reaction Unit	Oct., 1925	820
R382·8	The Inter-Electrode Capacities of Thermionic Valves, by L. Hartshorn, A.R.C.S., D.I.C., B.Sc., and T. I. Jones, A.R.C.S., D.I.C., B.Sc.	Feb., 1925	263
R383	A Variable Resistance for Radio Frequencies, by R. M. Wilmotte, B.A. (of the N.P.L.)	Aug., 1925	684
R384	Increasing the Range of D.C. Measuring Instruments, by E. H. W. Banner, M.Sc., A.M.I.R.E.	Feb., 1925	291
R384	Meters for Valve Transmitters, by S. K. Lewer	Oct., 1925	810
R384·009	A Useful Range of Meters. (Messrs. Heayberd, Ltd.)	Feb., 1925	281
R384·009	Precision Measuring Instruments	June, 1925	580
R386	Filters, by P. K. Turner	Aug., 1925	673
R386	Filters: A Supplementary Note, by P. K. Turner	Oct., 1925	821
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R387·2·009	A Useful Series-Parallel Switch. (Mr. Ernest Turner)	Mar., 1925	354
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R388	Distortion in Wireless Telephony and Related Applications of the Cathode Ray Oscillograph, Part I., by E. K. Sandeman and N. Kipping	Sept., 1925	756
R388	Distortion in Wireless Telephony and Related Applications of the Cathode Ray Oscillograph, Part II., by E. K. Sandeman and N. Kipping	Oct., 1925	811
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R401·24	Some Notes on 20-Metre Work, by E. H. Robinson (2VW)	Sept., 1925	767
R402	Short-Wave Receiver Notes, by R. A. Farmery	Nov., 1924	111
R411·0124	A New Method of Producing Ultra-Short Waves, by J. Taylor, B.Sc.	Mar., 1925	342
R423·0124	A Transmitting Circuit for Short Wave-Lengths, by E. H. Robinson	May, 1925	483
R440	Bedside Radio, by A. G. Wood	Nov., 1925	918
R460	Duplex Telephony, by P. P. Eckersley, M.I.E.E.	Nov., 1924	101
R499	For the Esperantists. (See under R800.)		
R519·6	Error in Measurements, by P. K. Turner	Mar., 1925	360
R519·8	More about Errors in Measurement, by P. K. Turner	May, 1925	512
R519·8	More about Errors in Measurement, by P. K. Turner	June, 1925	547
R530·4	Marine Wireless: Inaugural Address, by Major B. Binyon, O.B.E., M.A.	Dec., 1925	944
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R545·009·2	Long Distance-Work, by Hugh N. Ryan (5BV)	Dec., 1924	171
	Long-Distance Work, by Hugh N. Ryan (5BV)	Jan., 1925	240
	Long-Distance Work, by Hugh N. Ryan (5BV)	Feb., 1925	286
	Long-Distance Work, by Hugh N. Ryan (5BV)	April, 1925	441
	Long-Distance Work, by Hugh N. Ryan (5BV)	May, 1925	515
	Long-Distance Work, by Hugh N. Ryan (5BV)	June, 1925	582
	Long-Distance Work, by Hugh N. Ryan (5BV)	July, 1925	655
	Long-Distance Work, by Hugh N. Ryan (5BV)	Aug., 1925	720
	Long-Distance Work, by Hugh N. Ryan (5BV)	Sept., 1925	773
	Long-Distance Work, by Hugh N. Ryan (5BV)	Oct., 1925	850
	Long-Distance Work, by Hugh N. Ryan (5BV)	Nov., 1925	921
	Long-Distance Work, by Hugh N. Ryan (5BV)	Dec., 1925	980
R545·009·2	Round the World by British Wireless, by Major Wm. Coates Borrett (C1DD)	Oct., 1925	851
R545·009·2	Amateur DX in South America, by CH9TC (Los Andes, Chile)	Nov., 1925	930
R545·06	The Paris Conference	June, 1925	544
R545·06	R.S.G.B. Transmitter and Relay Section Dinner	June, 1925	572
R545·06	The Paris Conference: Report of Sub-Committee on the Organisation of the International Amateur Radio Union	July, 1925	623
R545·1	Amateur Transmission	Oct., 1924	55
R545·9	Wireless Field Work	Sept., 1925	772
R545·909	A Year Ago, by Leon Deloy (F8AB)	Feb., 1925	273
R589	In Praise of Atmospherics, by J. F. Herd, A.M.I.E.E., M.I.R.E.	Nov., 1925	892

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R612	An Amateur Station, 2GW, by J. Allan Cash	Mar., 1925	357
R612	An Amateur Station, 6NF, by Alfred D. Gay, F.C.S.	April, 1925	430
R612	An Amateur Station, 2OA, by E. A. Anson	May, 1925	474
R612	An Amateur Station, 2FP, by J. L. Pritchard	June, 1925	558
R612	An Amateur Station, 6TM, by W. A. S. Butement	Aug., 1925	700
R612	An Amateur Station, 5JX, by Marcus G. Scroggie, B.Sc.	Oct., 1925	823
R612	An Amateur Station, U2BRB, by B. H. J. Kynaston	Nov., 1925	894
R612	Re-opening CKAC—Montreal, by E. H. Turle, A.M.I.E.E.	Jan., 1925	231
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R621·355	The Theory of the Lead Accumulator, by N. A. de Bruyne	Jan., 1925	218
R621·374·4	Constructing a Suspended Moving Coil Galvanometer, by R. W. Hardisty, Student I.E.E.	April, 1925	404
R623·23	A Standard Report Card, by M. T. Coode	Aug., 1925	698
R650	Communication on Wave-lengths other than those in General Use, R.S.G.B. Lecture by G. G. Blake, M.I.E.E.	June, 1925	561
R800	A Short Radio Course of Esperanto, the International Language	Dec., 1924	174
R800	A Short English-Esperanto Dictionary of Radio Terms	Jan., 1925	243
R800	A Short Esperanto-English Dictionary of Radio Terms	Feb., 1925	307
R800	For the Esperantists: Pri l'Absorbo de Oudoj Mallongaj	Mar., 1925	370
R800	For the Esperantists	April, 1925	444
R800	For the Esperantists: Resumaro de Artikolojen E.W. & W.E.	May, 1925	517
R800	For the Esperantists: La Internacia Amatora Radio-Konferenco	June, 1925	584
R800	For the Esperantists: Resumaro de Artikolojen E.W. & W.E.	July, 1925	657
R800	For the Esperantists: Distordado	Aug., 1925	722
R800	For the Esperantists: Distordado	Sept., 1925	786
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R800 : R519·8	More about Errors in Measurement, by P. K. Turner	May, 1925	512
R800 : R519·8	More about Errors in Measurement, by P. K. Turner	June, 1925	547
R800 : R621·354	Testing Accumulators	June, 1925	573
R800 : R621·355	The Theory of the Lead Accumulator, by N. A. de Bruyne	Jan., 1925	218
R800 : R650	Communication on Wave-Lengths other than those in General Use, R.S.G.B. Lecture by G. G. Blake	June, 1925	561
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	Correspondence	Jan., 1925	248
	Correspondence	Feb., 1925	312
	Correspondence	Mar., 1925	374
	Correspondence	April, 1925	446
	Correspondence	May, 1925	520
	Correspondence	June, 1925	588
	Correspondence	July, 1925	661
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	Correspondence	Oct., 1925	856
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EXPERIMENTAL WIRELESS & The WIRELESS ENGINEER

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Editorial Views.

The Albert Hall Exhibition.

OUR readers may take it that as a general rule we shall not inflict upon them any account of the domestic troubles of the wireless trade. There are times, however, when these troubles have a direct affect upon the amateur, and this is one of them. It has been fairly widely advertised that a Wireless Exhibition is being held at the Albert Hall at the date on which these words appear; and some of our readers may be led by the name of the exhibition to expect it to resemble that at the White City last year. But they will be disappointed; for although many eminent firms will be exhibiting there, a large proportion of the goods in which readers of EXPERIMENTAL WIRELESS AND THE WIRELESS ENGINEER would be most interested—components and the like—have been excluded.

A few words are called for on the reasons for this peculiar position.

Some of the large and well-known firms of manufacturers have formed an association, the main object of which (according to its officers) is to settle, on a fixed basis, the terms on which wireless goods are sold by the manufacturer to the retailer. This Association, the N.A.R.M., or National Association of Radio Manufacturers, has for reasons of its own decided to exclude from the show which it has organised any of the following apparatus not made by its own members:—

(1) Complete broadcasting receiving sets.
(2) Sets of parts, unassembled (*i.e.*, constructors' sets).
(3) Amplifiers (valve or otherwise).
(4) Loud-speakers.
(5) Head telephones.
(6) Coils and coil holders.
(7) Condensers (fixed and variable).
(8) Transformers.
(9) Valve holders.
(10) Resistances (fixed and variable), and rheostats.
(11) Variometers and variocouplers.
(12) Plugs, jacks and sockets, including multiple distributors.
(13) Grid-leaks (fixed and variable).
(14) Crystal detectors (assembled or in parts).

Further, the members of the Association are bound not to allow their goods to be exhibited at other shows.

It is not for us here to discuss, from the trade point of view, the merits or demerits of these regulations. All that concerns us is that, instead of the hundred and fifty or more firms who might have exhibited, the show is confined to fifty or so, and will be by just that proportion less interesting and representative of what the industry can really do.

At the moment of going to press we hear that the excluded firms will almost certainly arrange to exhibit at a second show to be held elsewhere in London at an early date, so that everything will be exhibited after all. But why should the public have double trouble and pay double fees to further a trade dispute?

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Short Wave Radiation.

Among the many new problems set for us to solve by the recent work on short waves is that of radiation from an aerial on waves shorter than its fundamental. The attack from the mathematical side has already been made to some extent, but in most cases with simplifying assumptions which render it necessary, before accepting the analysis, to subject it to the test of experiment. Unfortunately the test is an extremely difficult one. It would appear that, if we regard the aerial as divided into separate parts, each independently oscillating, there is every probability that in certain directions there may be interference (in the optical sense) which may lead to the absence of radiation. Even if the aerial is symmetrical, as in the case of a plain vertical one, the radiation will not cover the whole free hemisphere from the zenith to the horizon, but may proceed along certain paths only, each forming a hollow cone. The directions in which there is radiation would seem to be affected by the loading as well as the aerial itself.

Extraordinary effects in long-distance work seem to be caused by slight alterations; but we should expect that slight changes in the Heaviside layer would also produce such effects, and it is hard to separate the two without a long series of tests most accurately carried out. It would seem that there is scope here for something in the nature of amateur "U.R.S.I." signals on low power and short wave, tests being made with various changes of aerial loading, etc., under all conditions of weather. Considerable co-operation would be required, as the tests would be useless without a considerable number of accurate receiving stations both near and far.

Mysterious Numbers.

For readers who may have missed the note in our last issue as to the arrangement of wireless books, cuttings, etc., a few words may be advisable in connection with the article on p. 3, and the reference numbers which appear at the right-hand side of the title of articles in this issue. Briefly, the article outlines a scheme, originated by Melvil Dewey and extended for wireless by the Bureau of Standards of America, for keeping books, press-cuttings, etc., in such order that everything connected with one subject is kept together, with allied subjects close to it; and the references in the titles of articles give the key numbers for those articles.

It will be found that in some cases the reference numbers are more detailed than those given in the article itself; but that need not interfere in any way with their use; it will be found that if all the articles were arranged in numerical order, they would also be (as far as practically possible) in logical order. We regret that various technical requirements of publishing prevent us from actually placing them in that order in the journal itself.

We may add that it is our hope to publish, in due course, not only an alphabetical index but a "subject index"; one in (more or less) logical order.

H.F. or L.F.?

In the September E.W. & W.E., Mr. S. R. Lewer expressed himself (in an article on "The Use of Low Frequency Amplification for Long-distance Reception") strongly in favour of L.F., to the disadvantage of H.F. In this issue Mr. F. C. Hogg joins issue with him, stating that for his part H.F. amplification is thoroughly successful.

Against most supporters of L.F. this would be a complete reply, for as a rule the only objection laid against high-frequency amplification is that of impracticability. But Mr. Lewer and (curiously enough) another contributor, in an article which we hope to publish shortly, attack it on various other points. Some of these points, we must confess, do not seem very cogent: for example, to cite selectivity as an advantage and "extra difficulty in tuning" as a disadvantage is hardly logical; they are different expressions for the same thing: one would hardly, when speaking of a top-hat, claim darkness as an advantage and at the same time point at absence of whiteness as a disadvantage!

It may seem unkind to put it so baldly, but we cannot help a suspicion that those who so eloquently point out the superiority of L.F. have had a little trouble with H.F. which further trials might show to be not entirely insuperable.

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The Arrangement of Wireless Books and Information. [025·4

We present below a sketch of the Dewey system and the Bureau of Standards extension of it, by which press-cuttings, books, etc., can be arranged in order.

THE general question of the classification of knowledge is a matter much too wide for us to enter into here. But it has its interest for many of our readers, perhaps quite unknown to themselves. We believe that there are thousands of our keener readers who have shelves full of books, back numbers of wireless periodicals, experimental logs, and what not, all containing useful information. But as soon as the collection becomes large, the information takes too long to find. Sometimes an attempt is made to get rid of useless matter by keeping only cuttings, but the real difficulty here is in arranging the cuttings.

As was pointed out in an editorial note in our last issue, an alphabetical arrangement fails miserably, because it brings totally unrelated subjects together. It is desirable to follow some scheme which presents a more or less logical classification of wireless subjects.

Now, as many of our readers will know, there are already in existence several schemes, used largely in libraries, which purport to classify all knowledge; or perhaps it is fairer to say which give a consistent scheme of arranging books, etc., on all subjects. For reasons which will become obvious later, we propose to give an outline of one that is perhaps the most famous of them all: the Decimal Classification of Melvil Dewey.

In this, all books or other written matter are divided into ten main classes, which are numbered :—

000	General works.	500	Science.
100	Philosophy.	600	Useful Arts.
200	Religion.	700	Fine Arts.
300	Sociology.	800	Literature.
400	Philology.	900	History.

Each of these ten classes is divided again, and we give the divisions of the two, 500 and 600, which most concern us :—

500	General works.	550	Geology.
510	Mathematics.	560	Palæontology.
520	Astronomy.	570	Biology.
530	Physics.	580	Botany.
540	Chemistry.	590	Zoology.

And, as regards 600 (Useful Arts) :—

600	General.	660	Chemical Manufactures.
610	Medicine.	670	The Metal Industries, etc.
620	Engineering.	680	Mechanics' Trades.
630	Agriculture	690	Building Trades.
640	Domestic Economy.		
650	Commerce.		

Now, coming down to our own particular interest, it is obvious that wireless might be treated as a department of Physics, which includes Electricity, or as a department of Engineering, which includes Electrical Engineering. It has seemed best to include it under the latter heading, and we will fall in with this decision, in order that our classification shall be consistent with those of others. We will therefore further examine 620. This is divided as follows :—

620	General	625	Roads & Railways.
621	Mechanical and Electrical.	626	Canals.
622	Mining.	627	Harbours, etc.
623	Military.	628	Sanitary Engineering.
624	Roofs and Bridges.	629	Other.

By now it will be fairly obvious to our readers that the space allowed for wireless work is, to say the least of it, hardly adequate. It is a fact that since the inception of the Dewey Scheme there has been an increase in the literature of Science and Engineering beyond all proportion to the importance of these subjects as viewed at that time. But it is one of the great beauties of the system that this makes little difference, as will be seen. It seems in these later days ridiculous that the whole of Electrical Engineering should form a sub-class of Mechanical Engineering, which itself is given only one-tenth the importance of "Mechanics' Trades"! Still there are such enormous

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advantages in adhering to the classification that we will continue. Class 621 is divided into :—

621·1	Steam Engineering.
621·2	Hydraulic Engineering.
621·3	Electrical Engineering.
621·4	Internal Combustion Engineering.
621·5	Compressed Air and Vacuum Engineering.
621·6	Pumping Engineering.
621·7	Workshops.
621·8	Parts of Machines.
621·9	Machine Tools.

And 621·3 is classified thus :—

621·30	General Electrical Work.
621·31	Dynamo-Electric Generation.
621·32	Lighting.
621·33	Traction.
621·34	Other Power Uses.
621·35	Voltaic and Chemical Generation.
621·36	Thermo-Electrics.
621·37	Electro-Chemical Applications.
621·38	Electric Communication.
621·39	Other Industrial Applications.

So that all telegraphy and telephony is rather hidden among "etceteras." The first mention of wireless itself occurs in the next sub-division, which is :—

621·38	Electric Communication.
·381	General.
·382	Telegraphy, Systems.
·383	,, Instruments.
·384	Wireless.
·385	Telephony, Systems.
·386	,, Instruments.
·387	,, Exchanges.
·388	
·389	Other Electric Communications.

So here at last we have it. In a general library the whole of our books or cuttings would be sub-divisions of the one number 621·384. The original Dewey had, of course, no provision for wireless at all, and the source of our further sub-classification is Circular No. 138 of the Bureau of Standards of the U.S.A., which extends the Dewey Scheme by a full classification of Wireless subjects.

In order to avoid the constant repetition of the figure 621·384, the B.S. (by which abbreviation we shall irreverently refer to the Bureau of Standards) propose to substitute for it the letter R. It would not do to omit some such key, for otherwise a number, say 520, might be mistaken for Dewey 520 instead of Dewey 621·384·520. Adherence to this makes it possible to give other books or matter their ordinary Dewey references.

The B.S. Extension.

This being understood, the B.S. extension proceeds thus :—

R000	Wireless in General.
R100	Theory and Principles.
R200	Measurements and Standardisation.
R300	Apparatus and Equipment.
R400	Systems of Working.
R500	Applications.
R600	Stations, and their Operation.
R700	Manufacture.
R800	(See below.)
R900	Miscellaneous and Sundries.

R800 is kept open for subjects not directly wireless : matter on mathematics, chemistry, programmes, and so forth, of which (if it were arranged on strict Dewey) some would come before and some after the purely wireless material. It is more convenient really to have one place for it.

Why a detailed list is needed.

Before we go into further sub-division, perhaps we may pause and see where all this is leading us. What is the object of it ? This natural question may be answered as follows. Suppose that you have fifty books, cuttings, etc., dealing with wireless, and that the parts of the subject which they individually deal with are fairly evenly divided among the various parts of the science. Then if you labelled each one with its class number, and put them on a shelf in numerical order, you would always quite easily find what you want. For example, an article dealing with 5XX would be under R600, and would easily be found among the four or five other station descriptions. But suppose you have two or three hundred cuttings, and are a specialist in broadcast reception. Then probably 90 per cent.—or say two hundred and fifty items—will all be put under R300, and you would have a terrible search.

So the B.S. extension has been carried further, in two distinct stages. There is a short list of 65 headings, covering main divisions for a small general collection ; and there is a larger list of about 600 headings, suitable either for a large collection or for a smaller collection which is specialised. A third, and very useful item, is an alphabetical index to wireless subjects, stating under what number they should be placed.

It is proposed to give here the short classification, and to give from time to time extracts of the full one. It must be realised that credit for the skill and labour expended

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on these lists is due entirely to the Bureau of Standards: to get the best out of the classification it is well worth while to get the Circular itself, which is easily obtainable.*

It is only fair to state that in reproducing the schedule we have in some cases substituted words commonly used in England where they differ from the favourite names in America (such as "valve" for "toob," etc.). We have also inserted some explanatory notes, and can only hope that the B.S. will consider our interpretation a satisfactory one.

One matter, of considerable help to the classifier, will first be brought forward. It will be noticed that throughout both Dewey and the B.S. extension, the "0" divisions are "general"; *e.g.*, 620, General Engineering; 621·30, General Electrical Works, etc. Now the further division of these classes follows a uniform scheme, depending mainly on the form in which the subject is presented: and this "form division" can be applied to any number throughout the scheme. Thus, as will be seen below, 007 signifies "Laws or regulations as to . . ." So that while R007 means "Laws as to Wireless," R520·07, since it ends with 007, means "Laws as to the use of Wireless for Aviation"; for the main scheme which follows gives 52, or 520, as "Wireless applied to Aviation"

We give these form divisions separately, to emphasise the fact that they can be applied anywhere.

* Circulars of the Bureau of Standards; No. 138; *A Decimal Classification of Radio Subjects—an Extension of the Dewey System.* Author not stated. To be obtained from the Superintendent of Documents, Government Printing Office, Washington, D.C., U.S.A. Price 10 cents plus postage.

The Form Classification.

·001	Statistics of . . .
·002	Quantities, costing, etc., of . . .
·003	Specifications, contracts, tenders, etc. (*not* Patent Specifications, for which see ·008). This, of course, is not much used by the private enthusiast.
·004	Designs and drawings of . . .
·005	Rules, administration, etc. This, like ·002 and ·003, is really for the professional.
·006	Working, operation instructions, maintenance of . . .
·007	Laws, legal regulations, etc., as to . . .
·008	Patent specifications as to . . .
·009	Test reports, logs, etc., as to . . .
·01	General theory of . . .
·02	Text-books on . . .
·03	Cyclopedias, glossaries and dictionaries of . . . (including signs and symbols.)
·04	Essays, lectures, papers read on . . .
·05	Periodicals, etc. This is provided for *information as to periodicals* (addresses, contribution rates, etc.), as well as for the journals themselves.
·06	Societies, institutions, exhibitions, etc. This again is for details as to the societies themselves as well as their transactions.
·07	Education, training schools, museums, etc.
·08	Tables, calculating charts, maps, etc.
·09	Historical and biographical notes.

With this preamble, we can come to the list itself: this being called by the B.S. the "abbreviated classification of Radio subjects." We shall call it the B.S. short scheme, although, in actual fact, we have included a few headings from the full scheme, so that this is rather fuller than the original B.S. short list.

R000 General.

An important class, looking after many items that could hardly be placed elsewhere. Remember, however, to place under more detailed headings further on matters which, although general, are yet confined to one branch: *e.g.*, R007 Laws as to Wireless generally; R540.07 Laws as to Private Installations.

	R007	Laws and regulations.
R030		Cyclopedias, dictionaries, glossaries, symbols, etc.
R050		Periodicals, bibliography, etc.
R060		Societies, institutions, and their proceedings and transactions.
R080		Collected tables, charts, and sundries, as under:—
	R081	Books of tables, etc.
	R083	Humour.
	R084	Maps.
R090		History of Wireless, and Biography.

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R100 General Principles and Theory.

This is a wide class: be careful to keep out of it matter of practical design and performance, which go under later headings.

R110 Wave motion and wireless waves and their behaviour.
R120 Aerials and their theory: for practical construction, see R320.
- R124 Frame aerials.
- R126 Earths.

R130 Valve theory: for actual apparatus and design, see R330.
- R131 Characteristics and general properties.
- R132 Amplifying by valves.
- R133 Oscillating valves.
- R134 Detecting by valves, including reaction and heterodyne.
- R135 Modulating by valves.

R140 The theory of circuits: such matters as resonance, inductance, beats, etc.

R150 H.F. generating apparatus, other than valves.

R160 Receiving apparatus: general matters such as sensitivity, tuning, etc.

R200 Measurements and Standardisation.

Under R200 itself come general points important in all measurement.

R210 Frequency and wave-length measurement and standards. The words "measurement and standards" apply also to the following headings:—

R220 Capacity.
R230 Inductance.
R240 Resistance, damping, and losses generally.
R250 Current.
R260 Voltage.
R270 Signal strength.
R280 Properties of materials (insulators, conductors, etc.).

R300 Apparatus and Equipment.

Under this heading come details and matters of design, as distinct from pure theory, which goes under R100. It will be noted that R100 and R300 are divided up on the same system.

R320 Aerial design.
- R322 Counterpoise.
- R324 Earth.
- R327 Artificial aerials.

R330 Valves; design, making, and particulars of.

R340 Valve apparatus.
- R341 Detectors.
- R342 Amplifiers and coupling.
- R343 Receivers (complete).
- R344 Generators: includes transmitters and also Heterodynes.

R350 H.F. generators other than valve.

R370 Receiving apparatus, apart from the valve circuits.
- R374 Crystals.
- R375 Other detectors (not valves).
- R376 Receivers (telephone), and indicators.
- R377 Recording.

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R380 Components and accessories.
- R381 Condensers.
- R382 Coils and H.F. transformers.
- R383 Resistances, grid-leaks, etc.
- R384 Wavemeters and similar instruments.
- R385 Keys, buzzers, and interrupters generally, also microphones.
- R386 Filters.
- R387 Shields, earths, insulators, etc.
- R388 Oscillographs.

R400 Systems of Working.

- R410 Damped and modulated waves.
- R420 C.W. systems.
- R430 Atmospherics, X-stoppers, secret systems, etc.
- R460 Duplex and multiplex.
- R470 "Wired Wireless."

R500 Applications and Uses.

- R510 Aids to navigation (D.F., etc.).
- R520 Aviation.
- R530 Commercial working.
- R540 Amateur work.
- R550 Broadcasting (*i.e.*, transmission: broadcast reception is R540). This also includes time, weather, calibration waves, etc.
- R560 Military and naval.
- R570 Wireless control of machinery, etc.

R600 Stations: Design, Operation, and Management.

- R610 Description of stations.
- R620 Operation, traffic, and management.

R700 Manufacturing.

This does not cover amateur constructional details, which are found under R300.

R800 Non-Radio Subjects.

As already explained, this is reserved as a convenient space for science or other matters used for wireless work, but not themselves wireless, *e.g.*, mathematics, workshop hints, etc. They will be arranged, preferably, in Dewey order.

R900 Miscellaneous.

If the other headings are properly understood, there should really be nothing here, but . . .

The scheme outlined above will cover many of the requirements of our readers. But for the sake of completeness, and to suit those who are professionally engaged or are in training as wireless engineers, we are going to give the full scheme as we can find space for it. We will commence forthwith with a first instalment, covering R000 to R099.

In certain cases we have gone rather farther than the B.S. full scheme itself. These numbers which we have taken the liberty of inserting are marked with a star: in this first instalment, most of them are derived from Dewey itself, or from what is known as the "Brussels Extension" of Dewey.

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The Full B.S. Extension.

(Numbers marked * are our own additions.)

R000 Wireless in General.

Note that the numbers 001 to 099 are also the "form division," and can be added to any number of the table, as already explained.

R001		Statistics, etc.
*R002		Quantities, costs, sale prices, etc. (This will not be used so much here as after individual numbers.)
R003		Contracts, tenders, specifications, etc. (not Patents—see R008).
R004		Designs, drawings, etc.
R005		Works executive, administration, personnel, etc.
*R006		Working instructions, maintenance, etc.
R007		Laws and regulations, arranged by countries.
	R007·1	U.S.A.
	·4	Canada.
	·5	British Empire.
	·6	France.
	·7	Germany.
	·8	Elsewhere.
	·9	International Conferences.
R008		Patent specifications.
R009		Reports, etc.
	*R009·1	On experiments.
	* ·2	On operation and traffic (log books, etc.).
	* ·3	On accidents, breakdowns, etc.
R010		Research: as a "form division," usually reserved for general considerations. Note that special research establishments come under R070.
	*R011	Definition of the science: general concept.
	*R012	Classification and special branches.
	*R013	Notes on the importance and utility of the science.
	*R015	Various theories.
	*R017	Units.
R020		Text-books, etc.
	*R021	Large and important treatises.
	*R022	General handbooks.
	*R023	Elementary works.
R030		Terminology, etc., cyclopædias, dictionaries.
	*R038	Glossaries of technical terms.
R040		Lectures, essays, technical papers, etc.
R050		Publications dealing with wireless.
	R053	Periodicals
	R055	Bibliography.
R060		Societies, institutions, etc.
	*R064	Exhibitions.
R070		Training, education, experiment.
	*R071	Courses of study.
	*R072	Research and experimental establishments.
	R073	Training of operators.
	*R074	Museums, etc.
	*R079	Examinations, competitions, etc.

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R080			Collected works, tables, miscellaneous works.
	R081		Tables (mathematical, etc.).
	R082		Nomograms, calculating charts, etc.
	R083		Humorous works.
	R084		Maps.
	*R085		Catalogues (commercial).
R090			History.
		R090·1	In U.S.A.
		R090·2	In British Empire.
		R090·3	In France.
		R090·4	In Germany.
		R090·5	In Italy, Spain, Portugal.
		R090·6	In Norway, Sweden, Denmark.
		R090·7	In Asia, Africa.
		R090·8	In S. America.
		R090·9	Elsewhere.
	R091		History of wireless telegraphy only.
		R091·1	In U.S.A.
		etc.	etc., as above.
	R092		History of wireless telephony only
		R092·1	In U.S.A.
		etc.	etc., as above.
	R097		Biography.

The next division, R100 (General Principles of Wireless) we hope to deal with in our next issue.

The Remote Control of Variable Condensers.

By Leonard A. Sayce, M.Sc., A.I.C. **[R381**

IN measurement work employing oscillating circuits it is frequently desirable to be able accurately to control the adjustment of one or more variable condensers. In many such measurements the capacity of the body and the hand introduce large errors if the dial of the condenser is moved in the ordinary way, and the long ebonite rods sometimes proposed are cumbersome. In all such cases the following very simple expedient has been found to give excellent results.

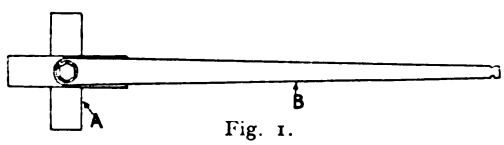

Fig. 1.

To the knob of the condenser is attached a clip (A, Fig. 1) bearing a fibre arm, B, some 15 cm. (6 in.) long. To the tip of the fibre arm a thread is attached, passing to a "winch" made of a piece of thin brass rod (C, Fig. 2), provided with a knob and turning stiffly in a cork, D. The cork may be clamped rigidly in a retort clamp. Turning the adjusting-knob thus winds up the thread and rotates the spindle of the condenser. The thread is kept taut and the spindle returned in the opposite direction by means of a rubber band, E. If the apparatus is available, the scale of the condenser is read by a telescope, F (a cathetometer is convenient) which is aligned upon a small mirror, G, fixed just above the indicating mark of the condenser scale and inclined at 45° to the vertical. The writer finds that a 6 in. diameter celluloid protractor makes a splendid scale for the purpose, for it can easily be read to $\frac{1}{10}$°. The above control

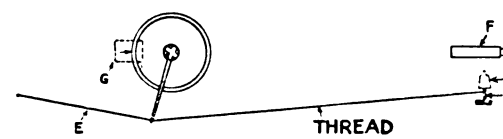

Fig. 2.

cannot move the spindle of the condenser through much more than 90°, but this is usually no disadvantage, for, if a greater range is required, the scale can be moved to its approximate position by hand—the fibre arm being free to turn stiffly—and the delicate adjustment is then made from a distance. There is practically no limit to the distance through which a condenser (or, indeed, any rotatable shaft) can be manipulated in this way.

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Effective Transmission.

By Hugh N. Ryan (5BV). [R113

I MUST blame this article chiefly upon several scientifically-minded experimenters who called me to book over a certain sentence in an earlier number of this journal.

In that note I was rash enough to state that a certain amateur station in Liverpool (2ZS) was working efficiently, since he had covered some four or five hundred miles with an aerial current of ·2 ampères. Since then, many people have pointed out to me, at greater or less length, that the efficiency of a station is not in any way connected with the ratio of distance to aerial power, and still less is it connected with the ratio of distance to aerial current.

In the face of all this, what can I do but admit the truth of the criticism, and plead weakly that I used the word "efficiency" for want of a better one?

Perhaps I had better find a suitable word for future use, and what could be better than "effectiveness"? The "efficiency" of a station is, of course, strictly speaking, the ratio of the power in the aerial to the input power. But this falls rather short of the true efficiency of a station, since wireless is, after all, fundamentally a method of communication between two or more places. This being the case, we experimenters should be working at the problem of covering greater distances per unit power. Many are apt to overlook this goal, and to devote their work to obtaining technical "output over input" efficiency, regardless of whether their large aerial currents are giving them any greater range than the man with the same input and less aerial power.

The efficiency of a transmitting set, considered merely as a generator of high frequency oscillations, is undoubtedly the ratio of H.F. energy to input, but considered as a radio transmitter, its ultimate efficiency is the ratio of range to input, which perhaps does not lend itself to such accurate measurement, but is much more important, and incidentally, much more difficult to obtain.

Do not imagine that I am decrying the purely scientific method; such is not the case. By all means get as big an aerial current as you can on a given power, but make sure that the range, besides the aerial current, bears some proportion to the power.

There are many experimenters who are really interested in their range, but take it for granted that if their aerial current goes up, their range will increase. This is not so, as shown by the results obtained by various amateur stations. For instance, 2KW, 2KF, 2ZS, 2UV and myself, amongst many others, have covered several hundred miles with aerial powers of the order of ·1 watt (*i.e.*, ·1 amp in aerials with average resistances of about 10 ohms.). Yet there are many stations with some fifty times this power who are never heard at a greater distance than about 80 or 100 miles. Also, it is not unknown for the same station to obtain better ranges on low power than on full power. This happened to me about a year ago, when I used low power on 200 metres, and devoted my time to getting the best possible range on that. Just before the American tests I increased the power considerably, without allowing time to carry out sufficient work on the increased power.

The technical efficiency of the set remained about the same. That is to say, I used about five times the input power, and obtained nearly five times the power in the aerial. But range fell off hopelessly, the distant stations who could still receive me reporting a great decrease in signal strength.

This effect is at present very noticeable in London in the transmissions of 5CX, of Colne. His signals are only just audible on one valve when his aerial current is about ·7 amp, but about four times the strength and easily readable when it is only ·3 to ·4 amp.

After saying so much about the evils of "Amp-worship," I will try to give you a few hints on how to make transmissions "effective" as well as efficient; but first let me say that I do not profess to explain the great discrepancy existing between the effectiveness of some high-power and

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low-power stations. It would be of enormous use to all if someone could produce a simple explanation, but I think, as things are at present, we can only improve things by careful attention to details. The various hints now given are the result of several years' experience of long-distance work on low power, not of "paper-work," and are open to any criticism which can be levelled at them.

The two most common causes of loss of useful power are harmonics and "spreading." The first is probably responsible for most of the trouble. In practice, the worst harmonic of a short wave transmitter is usually the first (this of course has a frequency of $2n$, and the aforementioned critics will tell me that 2 is an even number and the harmonic should not exist, but I am dealing now with practice, not theory). Then get someone with a receiver which will receive your first harmonic to listen for it. If he reports that it is of a strength at all comparable with the fundamental, start getting rid of it. This will be chiefly a matter of adjustment of mean grid potential, and of grid coupling. If two valves are used in parallel, and these are not matched, the harmonics are probably due to this cause. This is easily tested by removing one valve and noting whether the harmonic is lessened. If this proves to be so, use one valve and be content with a reduced aerial current rather than use both valves and waste part of your increased current in harmonics.

Now for "spreading." This is a most horrible fault, since it not only greatly reduces the range of a station, but it causes great and unnecessary interference to other stations in the same district. It is not pleasant to be jammed at any time, but when the jamming is quite unnecessary, and only caused by the bad adjustment of a transmitter, causing interference over a large ban of wave-lengths—but I had better return to the point before I am tempted too far from it, being a sufferer myself, in common with many Londoners.

The point with which we are concerned is that, if spreading is allowed to occur, range will suffer. A good, if not quite complete, analogy has been suggested by a well-known experimenter :—" If you empty a bucket of water over a floor, it won't go far, but it will make a mess locally ; if you pour it along a pipe it will go anywhere you like without any mess." This rather suggests directional transmission, but it expresses the facts well. An excellent example of this is given by 2OD. His transmissions are very sharply tuned, and seem to carry anywhere. They are not extremely strong in London, but are about the same strength at every place where I have listened to him, at distances up to about 100 miles.

Friends in Scotland tell me that he is nearly the same strength up there, and 8AB gets him without difficulty, although I have heard them working when 2OD was not so very strong in London.

Perhaps it would not be wise to take an example of the other sort ; it is sufficient to say there are stations which are not sharply tuned, and that the strength of these stations falls off greatly with distance.

The cause of spreading is not always obvious, but in general it is due to using a large power on a set designed for lower power (I know that "designed" suggests a commercially made set, but the trouble is that most of the spreading comes from the extraordinary people who buy a transmitter ready-made, and don't know what is inside the box). If a set has been made for fairly low power, and has inductances wound with thin wire with small or no spacing, spreading will usually result when high power is used. Badly smoothed A.C. or generator hum will cause some spreading, and such modulation of the C.W. should be avoided, though with care even raw A.C. can be prevented from spreading beyond the inevitable band between $(N-n)$ and $(N+n)$ where N is the radio frequency and n the A.C. frequency. There is evidently some other fundamental difference between an effective and an ineffective transmission of the same power and efficiency, but I think that the exact difference remains to be fathomed, as some of our most technically efficient stations do not get very good results in practice, and some of the people who do get very fine results seem to have struck their adjustments by experiments only, and cannot explain the great effectiveness of their transmissions.

I have myself worked Amsterdam with only ·001 watt in the aerial (·01 amp in a 10 ohm aerial) with a single valve receiver at the other end. If only I could get 1 ampere or so to behave like that ·01 amp, what range could I not cover ? Yet I am wondering whether I can span the Atlantic on 4 amps, with multi-valve receivers on the other side.

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The Performance and Properties of Telephonic Frequency Intervalve Transformers.

By D. W. Dye, B.Sc., A.C.G.I. **[R342.701**

PART II.

5.—Experimental circle diagrams. Effects of capacity connected to the secondary winding.

It is clear that information regarding the effective self-inductance and effective self-capacity of the secondary winding will be obtained by observing the effect on L_p and R_p of added capacity on the secondary winding. There are two methods of carrying out these experiments and each yields information of value; we can

(A) Obtain a set of circles each corresponding to a known added secondary capacity C_2. This gives all the information available from the experiments, but is rather laborious, since, on each circle, the resonant frequency is in a different region, and so a large number of frequencies must be chosen in order to obtain points around the upper portion of each circle.

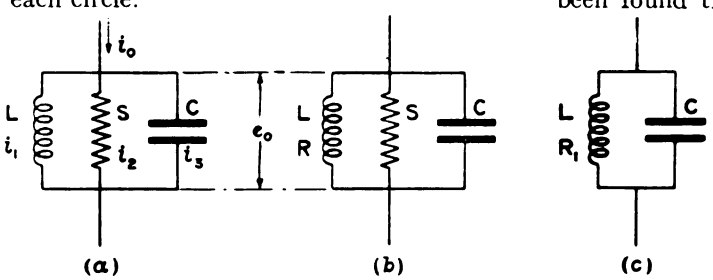

FIG. 9.

(B) We can choose a number of fixed frequencies and then find by variation of C_2 those values which give resonance on the secondary. We are, by this method, virtually finding the highest point T on each circle. This is easily accomplished experimentally by first obtaining the balance with the transformer disconnected from the bridge. Then, after connecting, adjusting V_2 to the chosen secondary voltage and disconnecting the voltmeter in the usual way, we obtain the second balance *without* alteration of M but by adjustment of C_2 and r. This method is simple to carry out and enables one to evaluate effective secondary inductance and equivalent secondary self-capacity in a direct manner.

Both sets of experiments have been made on the transformer, and are given below.

(A) Circle diagrams for various fixed secondary added capacities have been obtained, and are shown in Fig. 10. The added capacity consisted of a standard low range variable air condenser set to the successive values of 50, 100 and 150$\mu\mu$F. It was connected to the terminals SI, SO of the transformer. The four circles are distinguished by their dots to correspond to these capacities and to the case of zero added capacity. It will be seen that the circle for zero C_2 is not quite identical with that of Fig. 8. It has been found that the diameter and location of the points of the circle are slightly variable from one day to another. It is suspected that this is due to the magnetisation of the iron, since other experiments have indicated that the effective permeability and total losses of sheet materials at weak magnetisation are dependent upon the previous magnetic history of the material. For this reason it is desirable when making these observations, to complete a series at one occasion if information is sought on the relative diameters of the circles. With regard to the circles of Fig. 10, it is interesting to trace the effect of the factors operating. Reverting to Fig. 9 (*a*) it is seen that alteration of C should not have any effect on the diameter of the circle, which for this case is equal to S. But of course it is not C that we are varying, but C_2 across the secondary.

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The introduction of the R term also in (b) will explain the reduction in diameter with increasing capacity, and the diameters can be used as a means of evaluating the effective R of the transformer, which may include a part equivalent to some of the iron losses and also a part due to secondary resistance.

We have, as in (7) :—

$$R_p(max) \doteqdot \frac{S_1L_1}{L_1+R_1S_1C_1} \doteqdot S_1 \frac{R_1S^2C_1}{L_1+R_1S_1C_1}$$

If we take the difference ΔR_p in diameter of two circles corresponding to total equivalent primary capacities C_a and C_b we have

$$\Delta R_0(max) = \frac{L_1S_1{}^2R_1\,(C_a-C_b)}{L_1{}^2+L_1S_1R_1(C_a+C_b)}$$

(neglecting products of small quantities

$$\text{or } \Delta R_0(max) = \frac{R_1S_1{}^2\,(C_a-C_b)}{L_1+R_1S_1\,(C_a+C_b)}$$

Arranging for R, this becomes

$$R_1 = \frac{L_1}{S_1} \cdot \frac{\Delta R_p}{S_1(C_a-C_b)-\Delta R_p(C_a+C_b)} \quad .. \quad (17)$$

The secondary added capacity when referred to the primary winding will be approximately multiplied by $\sigma_0{}^2$, where σ_0 is the ratio of the secondary to the primary turns. In this particular transformer $\sigma_0 = 3{\cdot}5$ and $\sigma_0{}^2 = 12{\cdot}25$. If we take the extreme circles we have $\Delta R_p = 63\,000$; $C_a = 826\,\mu\mu F$ and $C_b = 825 + 12{\cdot}25 \times 150 = 2660\,\mu\mu F$.

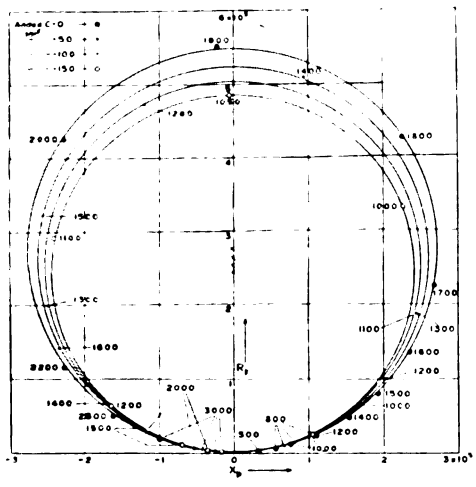

FIG. 10

From these quantities and the known values of L_1 and S_1 (in this case 8·8 and 582 000 respectively) we find $R_0 = 1060$. The direct current resistance is 1 000 ohms, so that this corroboration may be considered very good in the light of the fact that the effect of R is only in the nature of a correction.

If the values of L_1 and C_1 are deduced from one of the other circles it is found that the apparent C_1 has changed by an amount very nearly equal to $\sigma_0{}^2 \times$ added C_2, but there also occurs a small change in L_1 which is not clearly understood but may be

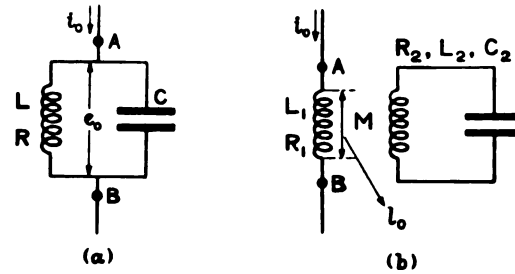

FIG. 11.

due to the load placed on the transformer or to the fact that a considerably different region of frequency forms the main portion of the circle. The effective L_1 is about 1 per cent. smaller for the case of an added secondary capacity of $100\mu\mu F$ than for the case of no added capacity.

We may now compare two simple cases as given in Fig. 11 (*a*) and (*b*), in which S has been omitted since it may be presumed to exist as a separate shunt across AB in both cases. We will compare the R_p and L_p in these two cases.

For (*a*) we have

$$i_0(R_p+L_pa) = i_1(R+La) = i_2\frac{1}{Ca} = e$$

$$i_0 = i_1 + i_2$$

$$\text{whence } R_p = \frac{R}{(1-LC\omega^2)^2+R^2C^2\omega^2} \quad .. \quad (18)$$

$$\text{and } L_p = \frac{L\,(1-LC\omega^2)-R^2C}{(1-LC\omega^2)^2+R^2C^2\omega^2} \quad .. \quad (19)$$

$$\text{or } (L_p-L)\omega \doteqdot \frac{L\omega LC\omega^2(1-LC\omega^2)}{(1-LC\omega^2)^2+R^2C^2\omega^2} \quad .. \quad (20)$$

in which R^2C has been neglected.

For case (*b*) we have $i_0(R_p+L_pa) = e$

$$i_0(R_1+L_1a)+i_2Ma = e$$

$$\text{and } i_2\left(R_2+L_2a+\frac{1}{C_2a}\right)+i_0Ma = 0$$

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whence

$$R_p - R_1 = \frac{R_2 M^2 C_2^2 \omega^4}{(1 - L_2 C_2 \omega^2)^2 + R_2^2 C_2^2 \omega^2} \quad .. \quad (21)$$

and

$$(L_p - L_1)\omega = \frac{M\omega M C_2 \omega^2 (1 - L_2 C_2 \omega^2)}{(1 - L_2 C_2 \omega^2)^2 + R_2^2 C_2^2 \omega^2} \quad .. \quad (22)$$

The expressions for $(L_0 - L_1)\omega$ in the two cases are of similar type and become identical if we put $M = \sigma_0 L_1$, $C = \sigma_0^2 C_2$ and $L_2 = \sigma_0^2 L$, where σ_0 = Ratio of secondary to primary turns.

It is seen therefore that as far as the effective primary resistance and reactance circle diagram is concerned the effect of capacity connected across the secondary winding is twofold.

Mainly, the points corresponding to given frequencies are shifted round the circle in an anti-clockwise direction so that the resonant frequency is lower, therefore for frequencies below this the impedance is greater whilst for frequencies above the resonance the impedance is less than it was before, *i.e.*, the performance of the transformer is improved for low frequencies but made worse for high frequencies.

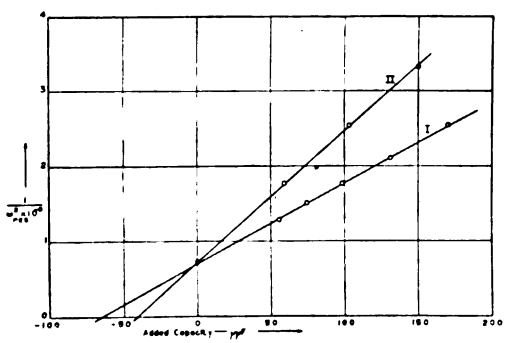

FIG 12.

The second effect of added secondary capacity is to slightly reduce the diameter of the circle, but the effect is of small consequence unless the added capacity is large.

We will now consider the results of experiments using the resonance method (b) of adjusting C_2 and r (see Fig. 6) to obtain a balance at various frequencies without alteration of M from its zero setting. By this means we keep the effective L_0 equal to zero. (This method of finding resonance of an oscillatory circuit of large damping is far more sensitive than any methods whereby a maximum voltage or current is obtained in the circuit when brought to resonance. A glance at the curve for L_p on Fig. 7 will show how rapid is the rate of change of this quantity at the resonant point). Fig. 12 (I) shows the straight line obtained when $1/\omega^2$ (resonance) is plotted against added secondary capacity C_2. The points are seen to lie on a good line which passes through the C axis at a value of C equal to —64·5$\mu\mu$F. This quantity therefore (with a plus sign), corresponds to the virtual effective self-capacity of the secondary winding—it must be corrected by about —1·5$\mu\mu$F for the leads connecting the small variable condenser to the secondary winding. The slope of the line gives the true effective secondary inductance. It is in the present case equal to 107 henries. The true primary inductance was shown to be equal to 8·68 henries. The ratio of the two inductances is 12·33 and the square root of this is 3·515. The ratio of turns is 3·50. It is seen therefore that the true inductances of the windings are very closely in the ratio of the squares of the numbers of turns.

If we multiply the virtual effective secondary capacity of 64·5$\mu\mu$F (as found from the line) by $12{\cdot}25 = \sigma_0^2$ we get the equivalent primary capacity of 774$\mu\mu$F. The total effective primary capacity was seen to be 825$\mu\mu$F. The difference of 50$\mu\mu$F may be considered as the true primary capacity and is probably not very much in error. The accuracy of this deduced value of C_p cannot of course be considered very high, since an error of only 1$\mu\mu$F in the virtual effective C_2 of 63$\mu\mu$F will produce an error of 12$\mu\mu$F in C_p. In any case the primary self-capacity is of very little practical consequence. The secondary capacity has been called a " virtual " effective capacity because the value deduced includes the effect, referred to the secondary terminals, of the mutual capacity between the open ends of primary and secondary. This matter will be referred to later when discussing the measurements on the effects of added mutual capacity.

When using this bridge method of determining resonant frequency by variation of C_2, we also observe r at the same time, and from it we can immediately deduce the diameter of the circle. For formula (7) may be written

$$\frac{1}{R_p(max)} = \frac{1}{S} + \frac{R_1}{L_1}\sigma_0^2 C_2 \quad .. \quad (23)$$

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and if therefore we plot $\frac{1}{R_{pmax}}$ against "added C_2" we should get a straight line whose slope equals $\sigma_0^2 R_1/L_1$ and whose intercept at a value of C_2 equal to

$$-\frac{825}{\sigma_0^2}\left(=-67{\cdot}5\right)$$

should give S.

The lower line of Fig. 13 shows the results of a series of such observations and indicates that equation (23) is fairly well satisfied. The slope of this line is equal to 1 620, giving R_1 the value about 1 150 ohms. It

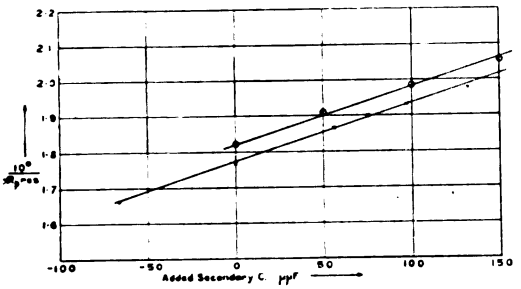

FIG. 13.

was previously assumed that R_1 was equal to the direct current resistance of the primary winding, but it is clear that the copper losses in the secondary winding must appear as an increase in the effective resistance of the primary. The secondary D.C. resistance is very nearly 4 000 ohms. The equivalent of this referred to the primary may be expected to be nearly equal to $4000/\sigma_0^2 = 327$ ohms, thus giving an expected total effective value of 1 327 ohms. The agreement between the calculated and deduced values of R_1 whilst not very close, may be considered satisfactory in view of the uncertainties involved in this deduction and the many factors operating.

On Fig. 13 another line is also drawn. The points on this line are those corresponding to the actual diameters of the four circles of Fig. 10. It will be observed that the slope is practically the same as that of line R, but that the line lies considerably above it. The variation from one day to another in the diameter of a circle has been remarked upon and is not fully understood. The observations by adjustment of C_2 were made on a different occasion from that on which the four circles were obtained. The parallelism of the lines, however, indicates that the general theory holds and that only the shunt resistance S is variable from day to day. The matter is of no consequence from the standpoint of performance of the transformer.

Effects of added mutual capacity.

The experiments on added mutual capacity (between the ends PI SO on Fig. 4) were made in precisely the same manner as those for secondary added capacity. The same standard variable air condenser was used connected to PI SO and a similar set of four circles were obtained. The points refer to a secondary terminal voltage of 2·0 in every case. They are shown in Fig. 14.

It will be seen that the circles are very similar to those corresponding to added secondary capacity. The points corresponding to any particular frequency are moved round in an anti-clockwise direction and the diameter is reduced as before.

It will be observed that the effects of added mutual capacity are more marked than those of added secondary capacity.

If we take the simple case represented by Fig. 15, it may easily be shown* that the effect of mutual capacity on effective primary impedance is exactly similar to that of

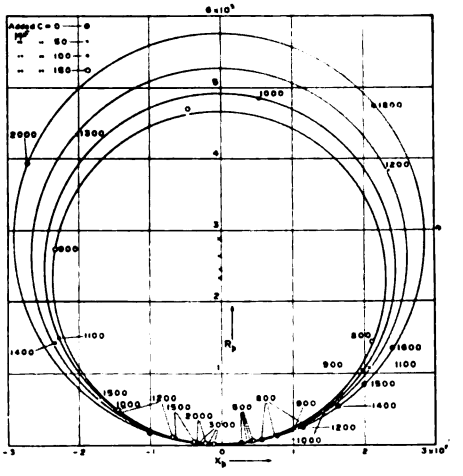

FIG 14.

secondary capacity and that it can be represented as an equivalent secondary capacity having the approximate value

$$C_2\,(\text{equivalent}) = C\,(\text{mutual}) \times \left(1 \pm \frac{1}{\sigma_0}\right)^2 \quad (29)$$

* See Note 1 at end.

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It is interesting to note the significance of the value and sign of σ_0. If the transformer has a large ratio, $\frac{1}{\sigma_0}$ will be small and the equivalent secondary capacity will be nearly equal to the mutual capacity. Again, if the direction of the windings is such that the primary and secondary voltages are approximately in the same phase (*i.e.*, M and σ_0 are negative), then the effect of mutual capacity is less than that due to the same capacity across the secondary. If primary and secondary voltages are in opposite phase, so that the potential difference across the condenser is greater than that across the secondary, mutual capacity produces a greater effect than secondary capacity. In a 1 : 1 transformer having the common point such that M is negative the effect of mutual capacity is negligible, since $\left(1-\frac{1}{\sigma_0}\right)^2$ is zero.

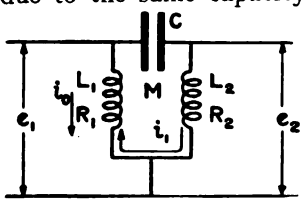

Fig. 15.

The expression for L_p including the effect of mutual capacity looks somewhat complicated,* but in the case of a good transformer the term

$$(1-k^2)\left[L_2C\omega^2\left(1\pm\frac{1}{\sigma_0}\right)^2-1\right]$$

is of little importance, since k is of the order 0·98 and the part in square brackets is considerably less than unity.

To a close approximation therefore

$$L_p \doteqdot \frac{\frac{L_2}{\sigma_0^2}\left(1-L_2C\omega^2\left[1\pm\frac{1}{\sigma_0}\right]^2\right)}{R_1^2C^2\omega^2+\left[L_2C\omega^2\left(1\pm\frac{1}{\sigma_0}\right)-1\right]} \quad .. \quad (30)$$

If we further treat the mutual capacity case in the same manner as that of secondary capacity, by determining the values of C_m corresponding to resonance, we shall expect to find a straight line connecting $1/\omega^2$ (resonance) and added C_m, having a slope equal to $L_2\left(1\pm\frac{1}{\sigma_0}\right)^2$ and an intercept equal to $\left(1\pm\frac{1}{\sigma_0}\right)^2$ times that obtained by the line for added secondary capacity. The line actually obtained from the resonances with various mutual capacities is shown on Fig. 12 (II). It is seen to be of greater slope than the other line, and must, of course, intersect it at the point C=0.

The actual slope was found to be 175·5 henries. Dividing by the slope of (1) (=107 henries) we get $(1+\frac{1}{\sigma_0})^2=1{\cdot}640$, whence σ_0—=3·57.

To be strictly accurate, we should have included k in the mutual term, *i.e.*,

$$\text{Effective } L=L_1+L_2+2M=L_2\left(\frac{1}{\sigma_0^2}+1+\frac{2k}{\sigma_0}\right)$$

instead of $(1\pm\frac{1}{\sigma_0})^2$.

Taking k=0·98 and σ_0=3·50 we get

Eff. L=107(1+0·082+0·560)=175.6, an agreement which is remarkably good.

(The measurement of k will be discussed later.)

The intercept on the C axis of the line (II) of Fig. 12 is at —40$\mu\mu$F which, allowing 1·5 for the leads and multiplying by $(1+\frac{1}{\sigma})^2$ gives —63·2$\mu\mu$F, a value very close to the value —63 given by line (I) of Fig. 12.

It is seen, therefore, from these experiments that the effects of secondary and mutual capacity are interpretable in terms of one another and of the ratio and direction of the windings (as shown by the approximate theory also).

As a result, it is not possible to separate the true effective mutual capacity and the true effective secondary capacity of a transformer by this method. It seems unlikely that any experiments will suffice to effect a separation unless a complete series of measurements is taken using all four of the possible ways of connecting primary and secondary windings together. If the connection between primary and secondary is charged, other mutual capacities will of course be brought into operation.

No attempt has been made in the present investigation to carry out this complete analysis, involving at least six capacities.

An easy way of separating the effective mutual and secondary capacities for the case of one particular common point between primary and secondary is, however, open to

* See Note 1 at end.

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those who construct transformers; that is to wind two transformers precisely similar in every respect, except that the direction of winding of the secondary of one of them is reversed as compared with the other. If the geometry of the windings of the two transformers is identical, then the only quantity changed will be the sign of σ_0.

We may consider the measured effective C_2 as made up in one case of

$$C_2 \text{ eff.} = C_s + C_m \left(1 + \frac{1}{\sigma_0}\right)^2$$

and in the other case,

$$C_2 \text{ eff.} = C_s + C_m \left(1 - \frac{1}{\sigma_0}\right)^2.$$

The values of C_2 eff. obtained on the two transformers will then differ by an amount equal to $\frac{4\,C_m}{\sigma_0}$ thus allowing C_m and C_s to be separated.

(c) *Effect of a shunt resistance across the secondary winding.*

Under some conditions, the grid-filament circuit of a valve has not an extremely high resistance. Also it is not uncommon for a resistance of one or two megohms to be used as a shunt on the secondary winding for the purpose of diminishing distortion. It is interesting, therefore, to analyse the effect of such a resistance. Experiments were

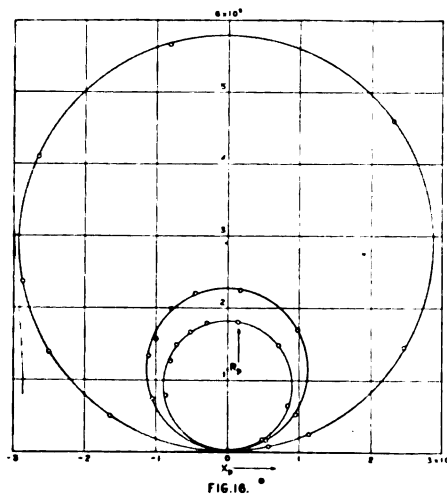

FIG. 16.

made using two grid leaks connected in turn by short leads to the secondary winding. The effective resistance of each was measured at a number of telephonic frequencies by shunting the leak across an air condenser of known value. The change in capacity and power-factor of the condenser was measured by a Carey-Foster bridge. The effective resistance and effective capacity of

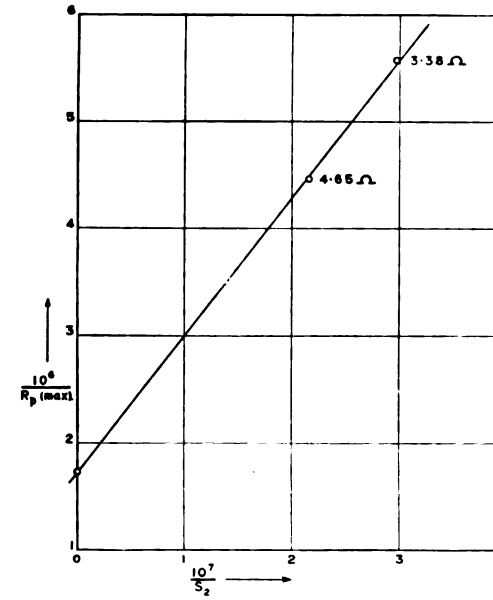

FIG. 17.

the leak were thus determined. The changes with frequency were small, the capacity also was only a very few micro-microfarads.

In Fig. 16 are shown three circles correponding to secondary resistances of ∞ 4·65 megohms and 3·38 megohms respectively. It is immediately seen that the effect on diameter is very marked. This reduction in diameter doubtless accounts for the greater stability and improved performance of transformers when used for telephony and music.

It will be observed that the impedance for low and for high frequencies is not much affected by a secondary shunt of 3 megohms, the main effect being on the impedance in the resonant region of frequency. Since, even with the shunt, the impedance at resonance is still of the order of 175 000 ohms, a large fraction of the available alternating voltage in the anode circuit will still be received on the primary of the transformer.

If we plot $1/R_p max$ against $1/S_2$, as in Fig. 17, we get—as might be expected—a straight line, of which the slope is found to be 12·50.

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The square root of this is equal to 3·53, a result of σ_0 in close agreement with the true value of 3·50.

(*d*) *Effect of magnitude of secondary induced electromotive force.*

Since various stages of amplification are concerned with considerably differing magnitudes of voltages, it was considered desirable to try the effect of varying the magnitude of the applied voltage.

This was carried out as follows: from the circle obtained for a constant induced voltage of 2·0 a few points of frequency were chosen so as to be fairly well distributed round it. At these frequencies observations were taken of X_p and R_p for various values of secondary voltage set by the help of the low-reading electrostatic voltmeter.

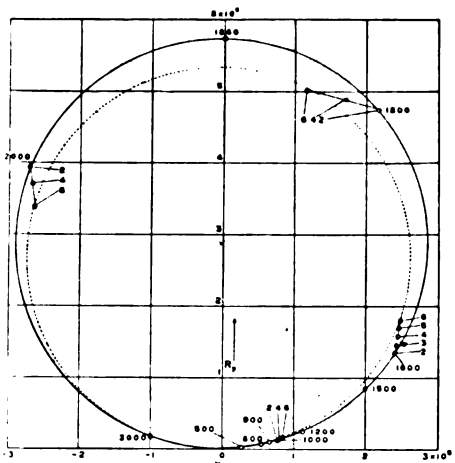

FIG. 18

The results of these observations are shown in Fig. 18. A number of interesting deductions can be drawn from the location of the points. The effect of the increased magnetisation necessary to produce an increased secondary voltage is to shift the points round in an anti-clockwise direction, doubtless due to increased permeability as the flux density rises. This effect is smaller the higher the frequency; this is no doubt due to the fact that the portion of the $\mathscr{H}\mathscr{B}$ curve explored at a higher frequency is moved down into a lower region of $\mathscr{H}$ and $\mathscr{B}$ at the higher frequencies, for the same range of voltage. Although the points on the curve for one frequency are more widely separated at the upper region of the circle, the corresponding change in effective L_p is nevertheless smaller. The explanation is, of course, that the scale of frequency is very much opened out over a large part of the circle and closes in towards the zero and ∞ points.

The next point to be noticed is that the circle joining the 6-volt points is smaller in diameter than that joining the 2-volt points. The explanation is that the hysteresis losses in the iron, at low densities, vary as a higher power of $\mathscr{B}$ than 2, consequently, as $\mathscr{B}$ diminishes the shunt resistance representing the total losses will increase. The indication is that over a very large range of amplification of secondary voltage, the amplification given by the transformer will not change much, and hence distortion due to variation in intensity should not occur on account of any variability in the constants of the transformer. As will be seen later, the circle may be profoundly modified by variation of applied voltage when a valve is connected to the secondary winding.

(*e*) *Effect on primary impedance when the grid-filament circuit of a valve is connected to the secondary winding of the transformer.*

The foregoing experiments must, of course, lead on to an examination of the behaviour of the transformer when performing its normal duty of supplying voltage to the grid-filament circuit of an ensuing valve.

The author has not had time to experimentally penetrate very far into the complicated region exposed by this problem, but it seems probably that the method of attack is a sufficiently powerful one to yield results of considerable value in analysing causes and effects associated with the various factors operating.

Only a very few experiments have been made, but the results are of a surprising nature, and show that profound effects may be produced depending upon the conditions in the attached valve circuit.

Three cases are given below and are shown in Fig. 20. The experimental arrangements were as in Fig. 19.

The bridge proper is identical with that of Fig. 6, but the arrangements for applying a known voltage to the transformer primary are somewhat different in order to enable smaller voltages to be conveniently measured. For this purpose a non-inductive resistance

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R_2 was used to enable small currents to be measured by the help of the electrostatic voltmeter V. Of this current (from 2 to 5 milliampères) the major portion passes through the shunt T. The terminal voltage on S can therefore be made a convenient fraction of that on R_2. The ratio will not alter appreciably due to the variations in the bridge, since it is almost non-inductive, and except in certain cases the shunting effect of the transformer primary across S is small.

(*b*) Similar to (*a*) but with constant primary alternating voltage to give a secondary voltage of 0.5 r.m.s.

(*c*) Grid at —4 volts and a secondary induced voltage of 2 volts r.m.s.

(*d*) Grid at 0 volts and a secondary induced voltage of 0·5 volt r.m.s.

A most remarkable variety of results was obtained, as shown in Fig. 20. For the purpose of comparison the normal circle with no connections on the transformer

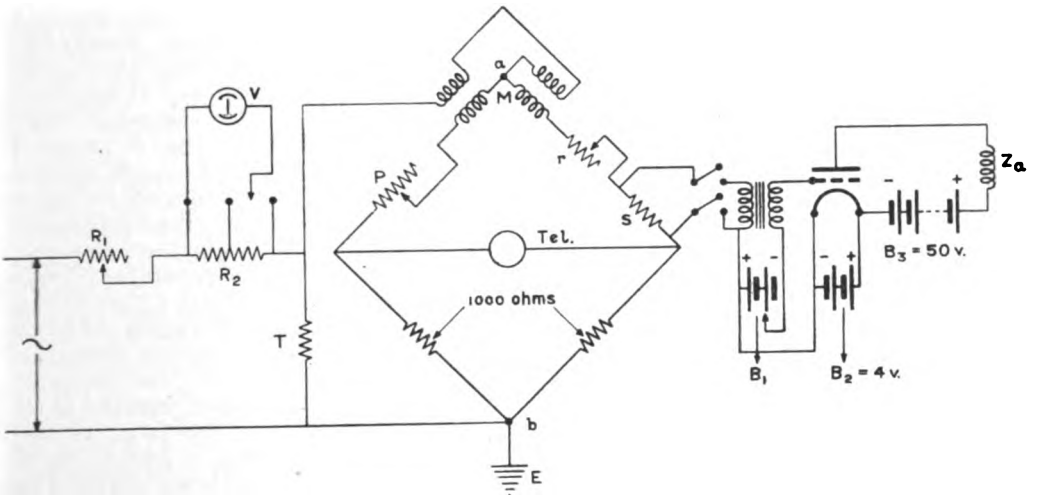

FIG.19.

The valve arrangements are indicated on the right of the diagram. The connections were such that a common point existed between primary and secondary windings of the transformer. The battery B_1 was for the purpose of maintaining the grid of the valve at a definite negative potential with respect to one end of the filament. The load Z_a in the anode circuit consisted of an inductance coil without iron. Its inductance was 5 Henries and its resistance about 1 000 ohms. The self-capacity was small (about 30$\mu\mu$F). It was placed at a considerable distance from the transformer, and was turned to a position of zero mutual inductance with respect to it. The following trial cases were taken over a range of frequencies from 500 to 3 000 cycles per second :—

(*a*) Grid at —2 volts steady potential, and a constant applied primary alternating voltage of ·57 volt r.m.s., corresponding to a secondary voltage of 2.

secondary is also shown, dotted. The other three circles are dealt with in order of their diameters, beginning with the smallest.

The following remarks are considered by the author to explain to some extent these results.

(*a*) *Applied Volts* 2, *Grid Volts* —2.

The circle is very small and somewhat distorted.

Since the applied alternating voltage on the grid has a r.m.s. value of 2 it will cause the grid to become positive during a part of the cycle, so that a heavy load is thrown on the transformer secondary which almost short circuits it during this part of each cycle.

(*b*) *Applied Volts* 0·5, *Grid Volts* —2.

The grid is always considerably negative with respect to the filament, and consequently the true internal grid-filament resistance is extremely high. Further

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explanation is needed, however, of the fact that the diameter of the circle is *greater* than that with open secondary. It is believed that the explanation lies in the nature of the load in the anode circuit. Miller* has shown that under certain conditions the input impedance of a valve can consist of a negative resistance and a capacity in series, in the case of an inductive load in the anode circuit. It may be that the increased diameter of the circle is a manifestation of this effect.

(*c*) *Applied Volts* 2, *Grid Volts* —4.

The circle is again large, although the applied alternating voltage has a r.m.s. value of 2. This is possible on account of the increased negative potential of the grid, which maintains it negative throughout the alternating cycle.

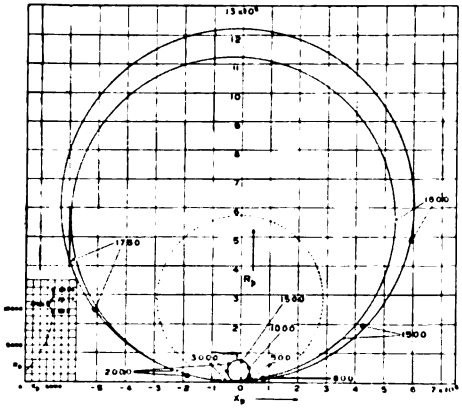

FIG 20

A remark may be permitted here regarding the conditions which should be observed if full use of the transformer is to be made.

If it is desired to obtain loud signals or speech, such as to necessitate the application of a few volts to the grid of a valve, then, in order to give the transformer an opportunity to keep a high primary impedance, it will be necessary to apply a considerable negative potential to the grid. Under these conditions, however, the valve will require a high anode potential in order to operate over the steep straight portion of its characteristic.

If it is not desired to use high anode voltage, then a large negative potential cannot be applied to the grid, and a step-up ratio on the transformer cannot be made use of at a loud-speaking stage on account of the heavy load placed on the secondary winding.

(*d*) *Applied Volts* 0·5, *Grid Volts* 0.

The impedance of the transformer no longer gives a circle diagram, but remains almost constant and of very small value. (It is so small as only to be seen on close inspection of Fig. 20 as a tiny sloping line near the origin.) The values obtained have been plotted on a much larger scale in the left hand corner of Fig. 20. It is seen that the impedance varies in a somewhat irregular manner, and is so small that it is doubtful whether any gain over a simple resistance or inductance coupling is made in spite of the step-up ratio of the transformer, owing to the smallness of the primary impedance.

These results call for much fuller investigation than the author can at present give them. The measurements under the heading (*b*) are difficult owing to the smallness of the energy available in the bridge. It has been found necessary to carry out the tests represented by the large circle at night under conditions of great quietness and steadiness; doubtless with some experimenting a stage of amplification could be applied to the bridge telephone without impairment of accuracy, so that the measurements could be made without special external conditions.

The possibility of increased diameter of the circle as a result of the conditions in the anode circuit of a valve probably has its counterpart in the howling noises occasioned by self-generation of currents of telephonic frequency. It is clear that the addition of a shunt resistance of one or two megohms on the secondary winding will effectively prevent the diameter of the circle from becoming infinite under conditions where otherwise distortion or howling might occur. No great loss of amplification will result from the use of a shunt resistance of 2 megohms, since this will still allow the circle to have a diameter of over 100 000 ohms in a normal transformer.

Another very convenient method of reducing the diameter of the primary impedance circle is to wind one or two turns of No. 18 or 20 S.W.G. wire round the

* Dependence of the Input Impedance of a Three Electrode Vacuum Tube upon the Load in the plate Circuit. J. M. Miller. *Bulletin Bureau of Standards*, No. 5351 Vol. 15, 1919-20, p. 367.

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outside of the secondary and to short circuit this tertiary winding either directly on itself or through a low resistance. Howling or incipient howling causing distortion may be prevented in this manner. The beneficial results which sometimes result from shrouding are probably due to the shroud acting as a closed tertiary winding in this manner and not to magnetic screening.

We must pass on to the consideration of the second part of the function of the transformer as mentioned in Section 2, namely, the effective voltage ratio.

ERRATA.—In the first part of this article, published in the September issue, one or two printer's errors unfortunately crept in. In column 2, page 695, the brackets in the denominator of formulas 3 and 4 should have been squared thus: $S^2(1-LC\omega^2)^2$, and not $S^2(1-LC\omega^2)$ as printed. In equation (13) in column 1, page 697, the part under the square root should have been

$$\sqrt{S^2-4X_2^2}, \quad \text{not} \quad \sqrt{S^2-4X}.$$

(To be continued.)

Note 1.—The Effect of Mutual Capacity.

We have

$$i_0(Rp+Lpa)=e_1=(i_0-i_1)(R_1+L_1a)-i_1M_a$$

$$(i_1-i_0)(R_1+L_1a+Ma)+i_1\left(R_2+L_2a+Ma+\frac{1}{Ca}\right)=0$$

$$i_1(R_2+L_2a)+(i_1-i_0)Ma=e_2$$

whence

$$Rp+Lpa=\frac{(R_1+L_1a)\left(R_2+L_2a+\frac{1}{Ca}\right)-Ma(R_1+L_1a+Ma)}{R_1+R_2+L_1a+L_2a+2Ma+\frac{1}{Ca}}$$

it will be found that

$$R_p=\frac{R_1\{(M+L_2)C\omega^2-1\}^2+R_2C^2\omega^2\{R_1(R_1+R_2)+(M+L_1)^2\omega^2\}}{(R_1+R_2)^2C^2\omega^2+[(L_1+L_2\pm 2M)C\omega^2-1]^2} \quad \ldots \quad (24)$$

and

$$L_p=\frac{L_1+C\omega^2\left[(L_1L_2-M^2)\{(L_1+L_2\pm 2M)C\omega^2-1\}-L_1(L_1+L_2\pm 2M)+(R_1^2L_2+R_2^2L_1-2R_1R_2M)C-\frac{R_1^2}{\omega^2}\right]}{(R_1+R_2)^2C^2\omega^2+[(L_1+L_2\pm 2M)C\omega^2-1]^2} \quad \ldots \quad (25)$$

Except at very low frequencies $R_1(R_1+R_2)$ is negligible compared with $(M+L_1)^2\omega^2$. Thus $R_1=1000$, $R_2=4000$, $M=\pm 30$, $L_1=9$ and let $\omega=2000$. Then $R_1(R_1+R_2)=5\times 10^6$ and $(M+L_1)^2\omega^2=1600\times 10^6$

We get therefore

$$R_p \doteqdot \frac{R_1\{(M+L_2)C\omega^2-1\}^2+R_2C^2\omega^4(M+L_1)^2}{(R_1+R_2)^2C^2\omega^2+[(L_1+L_2\pm 2M)C\omega^2-1]^2} \quad \ldots \quad (26)$$

$$L_p \doteqdot \frac{L_1\left[1+C\omega^2\left\{\frac{(L_1L_2-M^2)^2}{L_1}\left([L_1+L_2\pm 2M]C\omega^2-1\right)-(L_1+L_2\pm 2M)\right\}\right]}{(R_1+R_2)^2C^2\omega^2+[(L_1+L_2\pm 2M)C\omega^2-1]^2} \quad \ldots \quad (27)$$

or in terms of L_2

$$L_p \doteqdot \frac{\frac{L_2}{\sigma_0^2}\left[1+L_2C\omega^2\left[(1-k^2)\left\{L_2C\omega^2\left(1\pm\frac{1}{\sigma_0}\right)^2-1\right\}-\left(1\pm\frac{1}{\sigma_0}\right)^2\right]\right]}{(R_1+R_2)^2C^2\omega^2+\left[L_2C\omega^2\left(1\pm\frac{1}{\sigma_0}\right)^2-1\right]^2} \quad \ldots \quad (28)$$

in which $M^2=k^2L_1L_2$ and $L_2=\sigma_0^2L_1$.

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The Perfect Set. [R370

Part I: The Crystal Set.

This is the first of a series of articles dealing very thoroughly with a subject of great importance both to the advanced experimenter and the ordinary listener.

WE have adopted an ambitious title; and in justice to ourselves we must beg for a certain journalistic licence, for the perfect set is obviously an impossibility. The perfect set technically, even if it could be achieved, might be far from perfection when account is taken of cost and convenience.

What we really wish to do in this series is to take the old familiar types of set, with well-known circuits, and show a few points in which, by careful design, performance may be improved, both as regards strength and purity.

Starting then with the simplest set—the crystal—what can we do for it? One point immediately strikes the designer: since the crystal set depends for its results entirely upon energy received from the transmitter, and not upon its release from a local store as in the valve set, efficiency is more important than in any other set. Curiously enough, none of the vendors of commercial sets seem to appreciate this point: from their point of view, the crystal set is something to sell to a customer who has little money and therefore, needs no consideration. The writer is quite prepared to wager that by taking proper care the range (or signal strength) of a crystal set can be increased to at least 50 per cent. more than that of the average purchased set.

How is this to be done? Well, first, before going into detail, let us look at the general design. The crystal set comprises, in principle, three parts: an aerial circuit to transfer energy from the passing wave to the detector; the crystal, to transform H.F. energy from the aerial into L.F. energy for the phones; and the phones themselves to convert it into sound. Now it is a cardinal principle that in all such transformations of energy, the various parts must be suited to one another: one does not use a high gear for a steep hill, or a goods engine for an express train. Electrically, the rule is that when a circuit is supplying power, but is also unavoidably wasting some of the power, the best result is got when the waste power equals that passed on. This may seem at first unsound, or difficult to grasp. But let us apply it to a simple case. In Fig. 1 we have shown a dynamo giving a voltage E, which is sending current through a resistance R. Now, the smaller the resistance, the larger the current, and as the power is given by the current *squared* and multiplied by R, we find that decreasing the resistance to half its value will give twice the power; for we have twice the current multiplied by half the resistance.

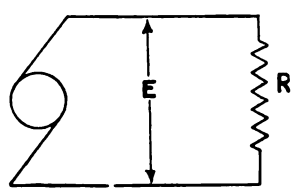

Fig. 1.

But now suppose that the dynamo itself has a resistance. Then halving the load resistance no longer doubles the current. For example, with a 12-ohm dynamo and an 8-ohm load, the *total* resistance is 20 ohms, and if the voltage generated is 20 volts the current is 1 amp, and the power in the load $1 \times 1 \times 8 = 8$ watts. If now we reduce the load to 4 ohms, the total is 16 ohms, and the current $20/16 = 1\frac{1}{4}$ amps. The power is $\frac{5}{4} \times \frac{5}{4} \times 4 = 6\frac{1}{4}$ watts: the decrease of resistance has caused an actual decrease of power. In this case the maximum useful power is developed by a load of 12 ohms: total resistance 24 ohms; current $\frac{5}{6}$ amp, useful power $\frac{5}{6} \times \frac{5}{6} \times 12 = 8\frac{1}{3}$ watts.

This golden rule of equal resistance for maximum useful power should never be forgotten in wireless work. We can at once find two applications for it in the crystal set. It would seem that the aerial, crystal, and phones should all have the same resistance. But this of course is not exact. We must consider not the resistance in each case,

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but the *apparent* resistance or effective resistance.

The actual value of this in the case of an aerial, a crystal, and a pair of telephones is most decidedly not a matter that we can go into in an elementary, non-mathematical article of this kind. But it can be stated clearly that the resistance of the average galena crystal is too low for the ordinary aerial circuit of to-day, and also too low for the telephones in common use. On the other

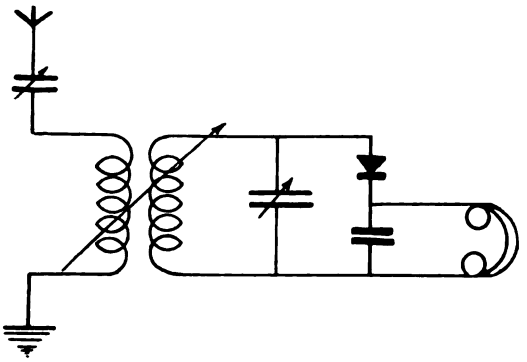

Fig. 2.

hand, galena is a good crystal, and the difficulty as regards the aerial circuit is easily overcome. We can regard the problem as that of supplying a low-resistance load from a rather high-resistance source. The obvious solution is that which we already use for low-resistance phones off a high-resistance valve—a transformer. We can use an actual transformer, as in the well-known "loose-coupled" circuit of Fig. 2, in which case the low resistance crystal is best suited by a fairly small secondary and large condenser (say a ·001μF condenser, and coil to suit). Or we can use a tight-coupled transformer, tuned on one side only, as in Fig 3*a* and *b*, the latter being often miscalled an "aperiodic aerial," which it isn't.

But except when we particularly want great selectivity at the expense of signal strength, when loose coupling is the thing, the simplest method is to get the effect of a tight-coupled transformer by using an "auto-transformer," which in practice means no more than using an aerial coil with a variable connection to the crystal. In its simplest form this goes back to very old times, when a favourite circuit used a long single-layer coil with two sliding contacts, as shown in Fig. 4—and, we might add, there are many worse schemes. If we want to use up-to-date apparatus, a simple scheme is to employ a variometer and variable condenser, as in Fig. 5. It is obvious that various settings of the variometer may be tuned to the same station by adjustment of the variable condenser; and one particular setting will give the best results of all. But this is rather a troublesome method, though free from the great disadvantage of Fig. 4—short-circuited turns. This can also be overcome by taking tappings from the coil to two switches.

The simplest method of all, though not the most efficient, depends on the assumption that with an average aerial and an average crystal, the best tapping point for the crystal will be about half-way up the coil. The crystal is, therefore, connected to the middle of the variometer, as in Fig. 6—an alteration which will be a great improvement in almost any bought crystal set.

Leaving this problem for a moment, let us consider the phones. It was stated above that the usual galena was too low in resistance to suit 2 000-ohm phones. Here, again, the obvious solution is a transformer, but an

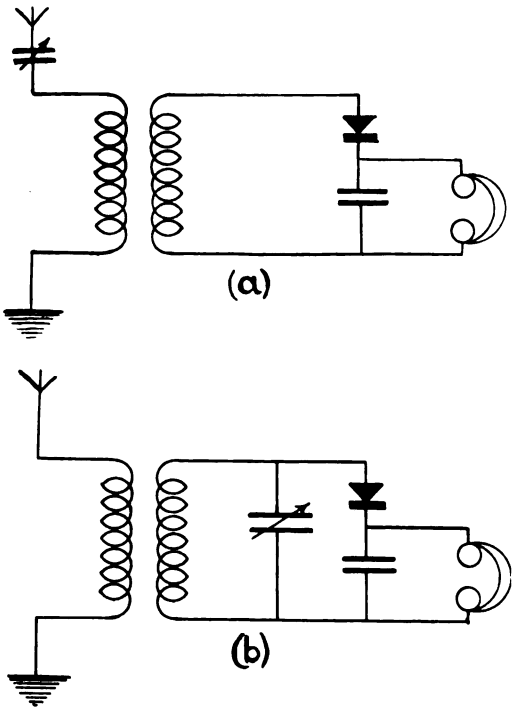

Fig. 3.

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iron-core telephone transformer has two disadvantages. Firstly, its primary, like the phones it displaces, is usually designed for a high-resistance valve circuit, and to wind a correct one is not a light task; secondly, such a transformer usually wastes quite a lot of power. Unfortunately, the phone windings themselves cannot be altered. But there is one simple modification which *can* be tried: the two ear-pieces can be connected in parallel instead of series, reducing the resistance from 2 000 ohms to 500. This will usually produce a surprising improvement.

Apart from these questions of balance, there are the matters of practical design from the efficiency point of view; and here there is an important point: a gain of 5 per cent. in output is not perceptible to the ear—even 10 per cent. will only be noticed by the experienced. But five gains of 5 per cent. give a total increase of 28 per cent., which is easily perceptible. So that if theory and experience say that such and such a modification gives improved efficiency it is worth doing, even if no obvious improvement seems to result. The two directions in which constructional design can improve matters are the diminution of (1) ohmic resistance; (2) dielectric losses. A third point is convenience, which is also a very important matter.

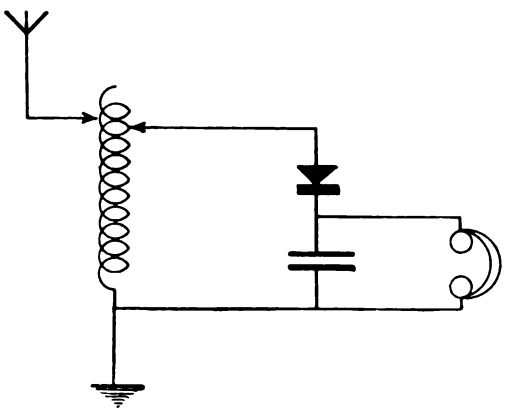

Fig. 4.

Coming down to practical design, what are we going to do about the coil? Mr. F. M. Colebrook, who has studied the question pretty fully, favours large square coils of bare wire, with clips for contacts. But this can hardly make a compact or pretty set. Undoubtedly, the square coil is the most efficient, for it can be arranged so that each turn is only in contact with solid matter at four points. The basket coil has many adherents, but it suffers from this: that where the turns cross one another, the insulator between them (cotton as a rule) is one prone to set up quite a surprising loss. The coil with an absolute minimum of solid matter is probably that built like a miniature frame aerial. Two pieces of ebonite of the general shape of Fig. 7 are cut, and fitted together to form a cross: the wire is wound in the slots. The most effective order of winding is a rather peculiar one, and is given by the numbers in Fig. 7. One turn is wound on the front, then two on the back, after which the turns go two in front and two behind.

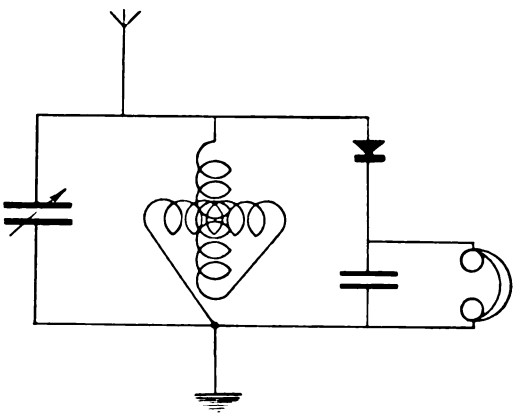

Fig. 5.

It is well known that there is a best size of wire for such coils. The actual best size varies with the type of coil and the frequency; but for broadcast waves is probably 18 to 20 S.W.G. Stranded wire is only useful if (A) every strand is fully circulated, (B) the strands are plaited or most carefully twisted, (C) very great care is taken to make soldered contact to *every* strand. As our coil is to be tapped this is impracticable. Theoretically, silver plated wire would be an advantage. Actually, bare wire or enamelled is quite all right: tinned wire is not quite so good. A coil of about 50 turns is likely to be sufficient if the diameter of the inside turn is about 2 in.

Now as to tuning. It has always seemed to the writer that the simplest method is to tune the aerial circuit by a condenser. The adjustment of the crystal circuit,

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however, must be by a tapping on the coil. A clip means that the coil must be exposed, and as the crystal adjustment is not a very sharp or sensitive one, it seems reasonable to use a multi-stud switch. It is extremely

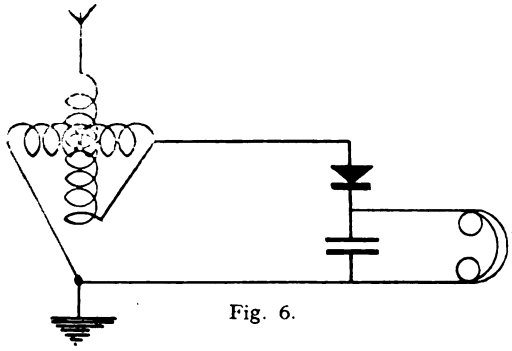

Fig. 6.

unlikely that the best result will be given by much less than half the coil, so if 50 turns are used seven tappings, including 50, 45, 40, 35, 30, 25, 20 turns, will suffice. Undoubtedly, a switch with its tappings does not form such an efficient scheme as a short flex lead and a clip: but the loss need not be large if care is taken.

The tuning condenser, however, must not be dismissed without thought. The home-made condenser is at a disadvantage because aluminium plates are used. These are *always* covered by a film of transparent oxide, which re-forms immediately, even if it is removed. Hence, it is by no means easy to ensure really good contact, especially as solder will not adhere. If possible, use a condenser with brass or zinc plates and ebonite ends, or if metal ends are used, see that the insulating bushes are *large*.

The detector itself merits consideration. Assuming that galena is to be used, the important thing (granted that the insulating parts of the detector are of ebonite and not erinoid or such material) is a stable and fine adjustment. There are many detectors available now in which the contact point has a screw adjustment, which is the first step. But this is not enough. Few detectors employing a ball joint can be called stable. A better type is that in which the crystal cup and the point holder have cross movements so that every point of the crystal can be reached without a ball joint. There are several such on the market.

A very important point in any crystal set is to have two entirely separate detectors with a switch. It is useless to try and adjust a detector with no standard of comparison: by using two and testing each against the other, one can find the really sensitive points. This tip alone may be worth 25 per cent. in signals. Fancy detectors with multiple cups, etc., miss the point; the two detectors must be entirely independent.

Also, there is the potentiometer question. The writer has tested, on the average, two or three crystals a week for the past year (most of them galena under various names), and there was not one, within his recollection, which would not have been improved by a small voltage—about ·1 to ·2 for most of the galenas.

A useful hint is to stretch a piece of fine chiffon or silk net over the crystal, so that the point works through the mesh and is thus held in position. For those who can use it properly, Woods' metal is undoubtedly superior to springs, etc. for holding the crystal owing to the excellent contact made by it.

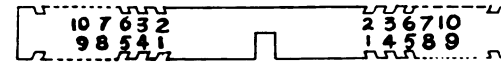

Fig. 7.

Lastly, do not omit a condenser across the phones. If this is not used, one depends on the capacity of the phones and cords to by-pass the high-frequency currents. This sometimes causes quite heavy loss. Another disadvantage is that it increases the tendency for the tuning to be affected by the nearness of the hand to the condenser, owing to leakage through the body from the hand to the phones. If the phones are shunted by a condenser of ·002 or so, both sides of them will be practically at earth potential, and if care is taken to make the moving plates of the condenser also on the earth side, this effect will not be noticeable.

The time has now come when we can begin to lay out the actual detail design of a good crystal receiver, and this is where we stop. It is not our purpose to give detail designs, for we hold that this is the branch where personal taste should hold sway. Any set built on the principles we have outlined will do well, if the common precautions of wireless construction are taken. In our opinion there is too much written about detailed construction these days, and not enough about principles; and we have endeavoured to fill in some of the gaps in the latter division.

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High-frequency Resistance. [R240

By J. H. Reyner, A.C.G.I., B.Sc., D.I.C.

A FACTOR which exercises considerable effect on the working of a wireless circuit is the high-frequency resistance of the component parts. There are two classes of high-frequency resistance—one due to the ordinary physical effects at higher frequencies, and the second class which is due to defective construction, such as partial short circuits between turns of a coil, poor insulation in condensers, etc.

The increase of circuit resistance as the frequency is increased is to a large extent unavoidable. There are several ways of regarding the phenomenon, but, without going into considerable detail, it may be mentioned that, as the frequency increases, there is the well-known skin effect, and also eddy current losses in the material of the coil or condenser itself absorb an appreciable amount of energy. The result of this is to increase the effective resistance of the circuit, and the high-frequency resistance may be many times as great as the direct current resistance.

The increased resistance effect is chiefly noticeable in coils, and various methods are adopted to combat it, the trouble taken depending on the seriousness of the ultimate effect on the circuit. For example, in receiving units employing reaction the effect is of little consequence since the increased resistance can be compensated for by an increased reaction; in transmitting circuits on the other hand, every effort is made to keep the H.F. resistance down.

The second case, however, where the high-frequency resistance is not accounted for by the physical laws just referred to, is a more serious matter, and the author has found H.F. resistance due to defective construction responsible for many snags in the operation of receivers. In one case the circuit refused to function properly right from the start, the tuning being blunt and the results bad. It was found that the wire used in winding the coils had poor insulation, which was accentuated by bad wax. In another case the coils gradually developed a high-frequency short after some months of use. As a result methods were devised for checking the H.F. resistance, and the test proved very valuable.

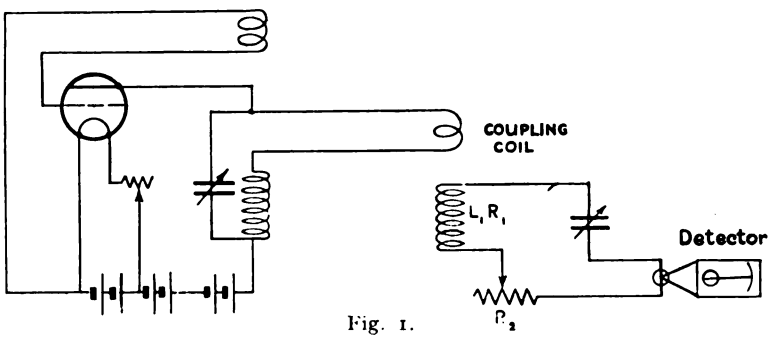

Fig. 1.

Methods of Measuring H.F. Resistance.

There are two methods in common use for this class of measurement, but unfortunately both of them necessitate the use of apparatus not usually in the possession of amateurs.

It has been pointed out, however, that in receiving circuits, it is only the "unauthorised" H.F. effects which cause serious trouble, and fortunately there is a simple method of detecting such faults.

Simple Routine Test.

Consider a simple circuit, as in Fig. 1. When the test circuit is tuned to the oscillator, maximum current flows on the circuit. If a brass or copper disc is placed near the coil, the current immediately drops to a very small value, due to eddy current losses in the disc.

If a suspected coil is brought near the main coil, a similar effect will happen if the coil is faulty, while no diminution will result if the coil is "O.K." This applies in all

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cases unless the natural frequency of the suspected coil is the same as or near to the frequency in the test circuit, in which case

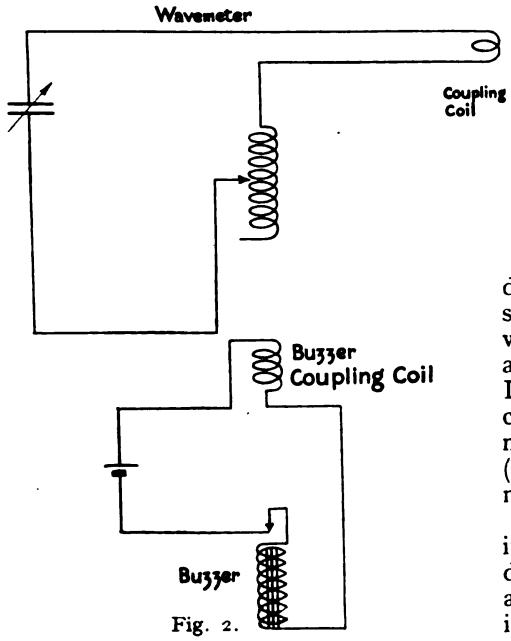
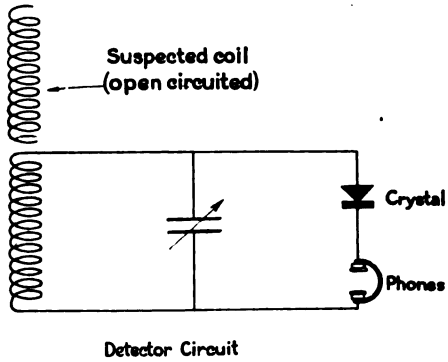


Fig. 2.

the latter may be altered to some totally different value.

Suitable Amateur Circuit.

For amateur purposes it is not necessary to use a valve oscillator, and a crystal



detector may be employed. Fig. 2 shows a suitable arrangement. A simple buzzer wavemeter is coupled to a detector circuit and the latter is tuned for maximum signals. If a faulty coil is placed on top of the detector coil the signals will at once die away, while no effect will be observed if the coil is O.K. (subject to the natural frequency proviso mentioned above).

The wavemeter should cover a large range, including any wave-lengths on which it is desired to work. The coil should be tested at or around the wave-length on which it is proposed to work. If there is any doubt as to whether or not the suspected coil is resonating with the test circuit, readings should be taken at two widely differing wave lengths.

This method has the merit of simplicity, and, even if infrequently used, will effect a large saving of time and worry.

Valves, French and English. [R330·09

It is interesting to compare typical modern French valves, as exemplified by the two tests which follow, with the result of similar tests on British 60mA types. It will be noted that there are distinct differences in the general performance.

Métal.

This sample was handed to us for test by the Gerrard Radio Stores, 15, Little Newport Street, W.C.2, who are handling it in this country. In outside appearance it is in no way out of the ordinary; but the electrodes are arranged horizontally, as in the "R" valve, instead of vertically as in the case of most British ·06 valves.

There was no definite information as to rating, so the valve was tested at 2·6, 2·8, 3·0 and 3·2V on the filament. As will be seen from the table below, the filament took rather less than its rated current.

MÉTAL.

Fil. Volts. E_f	Fil. Cur. I_f	Sat. Plate Cur. I_s	Anode Imped-ance. R_a	Voltage Ampli. μ	Power Ampli. P $\left(=\frac{1\,000\mu^2}{R_a}\right)$	Filament Efficiency. F $\left(=\frac{I_s}{\text{Watts.}}\right)$
V.	mA.	mA.	O.			
2·6	48	1·5	50 000	12·8	3·2	12
2·8	52	2·3	48 000	12·8	3·4	16
3·0	54	3·1	46 000	12·8	3·6	19
3·2	56	4·2	44 000	12·8	3·8	23

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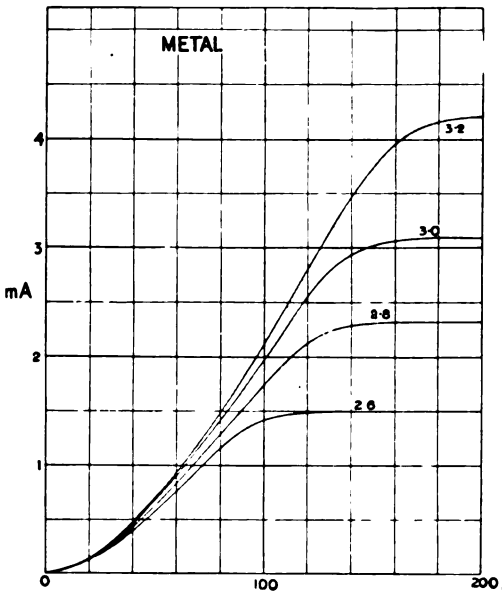
We note also that the "filament efficiency" (mA of saturation current per watt input) was low, 2·3 being not a high figure for a filament of this type.



The saturation current itself, 4·2mA at 3·2 volts, fits in with these other figures, and leads us to believe that the filament is of a higher resistance than in similar British valves, so that more than 3V is really advisable. Under such conditions better figures would be obtained for output and efficiency.

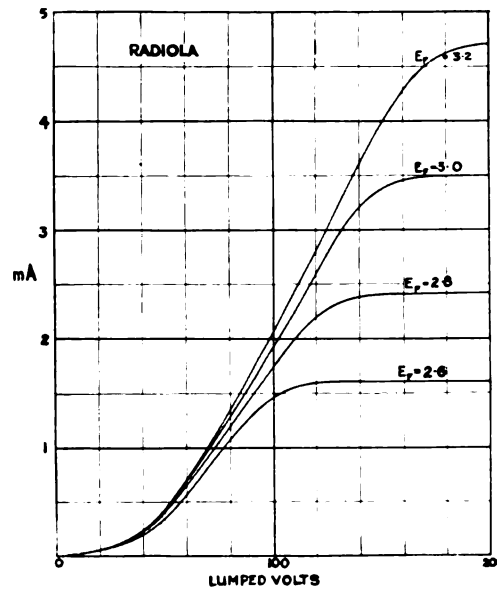
As regards amplification, the valve is very good. It has a high μ (12·8) and although the anode impedance is naturally high compared with British valves of lower μ, the power amplification factor $\frac{(1\,000\mu^2)}{R_a}$ is quite high, even at this low filament heat.

The valve is not particularly microphonic, as compared with other ·06-amp valves. Eccles lumped characteristics are shown in the accompanying curves.

Radio-Micro.

This, another French ·06 valve, is handled in this country by H. Lloyd Marshall & Co., 43, Blackfriars Road, London, S.E.1. It is arranged on very similar lines to the Métal valve noted above, with horizontal electrodes. It is easily recognisable, however, by its dumpy bulb.

Its behaviour is, generally, similar to the other French valve tested. It would probably give its best output at more than 3V on the filament. As will be seen from the table, it has a rather lower μ and R_a, but a slightly higher output. Characteristic curves, as can be seen from the figure, show a quite exceptionally long "straight" part to the curves, so that the valve should be particularly good for the early and intermediate stages in an L.F. amplifier.

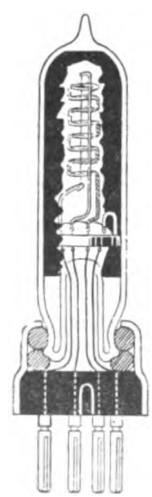


RADIOLA.

Fil. Volts. E_f	Fil. Cur. I_f	Sat. Plate Cur. I_s	Anode Imped-ance. R_a	Voltage Ampli. μ	Power Ampli. P $\left(=\frac{1\,000\mu^2}{R_a}\right)$	Filament Efficiency. F $\left(=\frac{I_s}{\text{Watts.}}\right)$
V.	mA.	mA.	O.			
2·6	52	1·6	40 000	10·0	2·5	12
2·8	54	2·4	39 000	10·5	2·8	16
3·0	57	3·5	37 000	10·5	2·9	21
3·2	60	4·7	35 000	10·5	3·0	25

G.W.I. Plateless.

This is in many ways a most interesting valve. It is made by G.W.I., Ltd., Imperial House, 43, Grafton Street, Tottenham Court Road, W.1. The word "plateless" is, of course, a misnomer, though the valve has no anode of the usual construction. Instead, the inner surface of the glass itself is silvered, and acts as anode. The grid construction (a French patent) is also unusual: it is shown in a sketch reproduced from the maker's illustration.



The valve is a bright one, the maker's rating being 3½—6V, ·3 to ·5A. On actual test, it was found that this rating was wide of the mark, the filament current being ·74A at 3·2V and .89A at 4·4V.

Although the bulb is of a long and narrow shape, the effect of using its interior surface as

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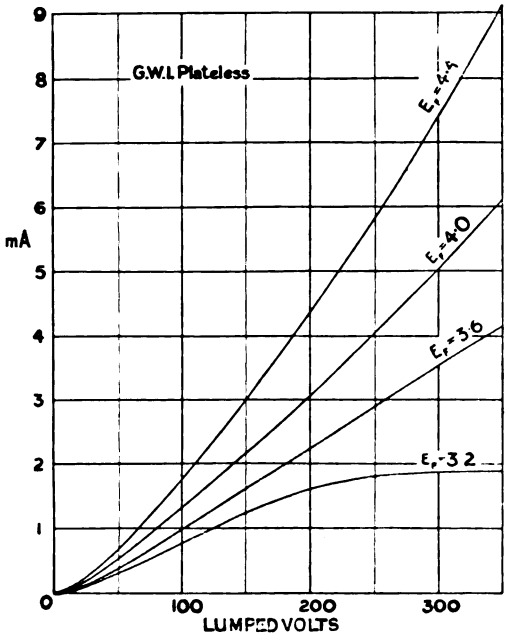
anode is naturally to produce a valve with electrodes spaced rather far apart, this giving a high impedance. The amplification is also high, resulting in a power amplification factor of normal value.

It will be seen from the table that the saturation current is also exceptionally high, and it is a



consequence of the high μ and R_a that a very large anode voltage is necessary to get saturation. The characteristics are, in fact, very curious, as will be seen from our drawing; it will be seen that at 300 volts there is no sign of saturation except at 3·2 filament volts; that there is a most exceptional change of slope with increased filament heat, and that the "lower bend" of the curves is unusually sharp.

G.W.I.

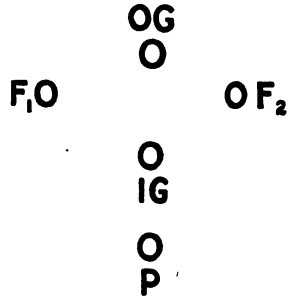
Fil. Volts. E_f	Fil. Cur. I_f	Sat. Plate Cur. I_s	Anode Imped-ance. R_a	Voltage Ampli. μ	Power Ampli. P $\left(=\frac{1\,000\mu^2}{R_a}\right)$	Filament Efficiency. F $\left(=\frac{I_s}{\text{Watts.}}\right)$
V.	A.	mA.	O.			
3·2	·74	1·9	150 000	18·5	2·2	·8
3·6	·80	6·0	80 000	14·0	2·5	2·1
4·0	·84	18	50 000	12·3	2·8	5·5
4·4	·89	25	43 000	10·5	2·8	6·2

A curious point is that if any current over 1mA or thereabouts is being passed, the bulb soon gets very hot from bombardment: quite hot enough to give a most unpleasant burn.

As will be seen from our illustration, a special method is employed to hold the valve in the cap, a ridge on the foot being gripped between two rubber rings.

A Four-Electrode Valve.

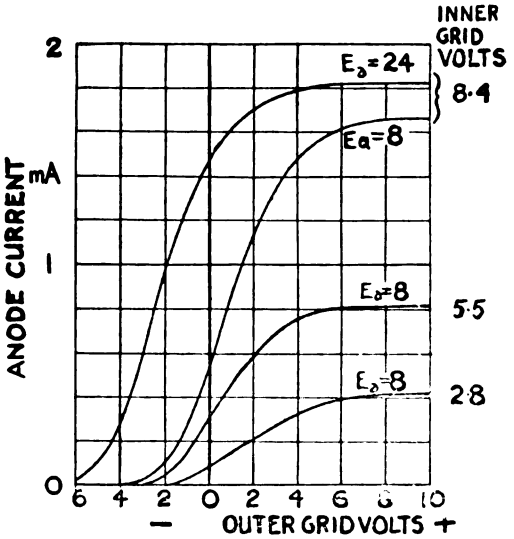
This is a French valve, supplied by the Gerrard Radio Stores, mentioned above. Our photograph shows the general arrangement, and in a separate sketch we give the type of holder required.



Sketch, not to scale, of the type of holder required for the four-electrode valve.

In testing out a four-electrode valve, it is hardly useful to apply our usual routine trials, while to provide curves for each change of variable—filament heat, inner grid volts, outer grid volts, plate volts, with the appropriate currents in each case—would take something like a complete issue of E.W.& W.E. So we have compromised by investigating the suitability of the valve for two well-known circuits of the present day: (1) its performance with low anode volts assisted by a steady positive voltage on the inner grid, with input on the outer grid; (2) its performance in the Marconi ship reflex circuit, with input to inner grid, output from outer grid, and rectification by the plate.

From the first point of view, the anode was held at +8V (4V above filament positive). Curves were then taken by varying the outer grid volts, while the inner grid was given a fixed positive voltage, different for each curve. The results are shown in Fig. 1, and show the usual type of result, the inner grid voltage having an effect like that of changing filament heat in a three-electrode valve. A fourth curve shows the effect of increased anode voltage. Working from the two curves for E_{og}=8V, we find μ=14, R_a=24,000. The valve does not, however, give of its best in this



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circuit, as better results are obtained with a pattern of lower μ and R_a.

For use in the Marconi circuit, however, the valve is much more promising. Two tests were made, corresponding to the amplification and rectification required. The first was to maintain the plate at 0V, and take curves of outer grid current against inner grid voltage for various values of outer grid volts, the outer grid acting like the plate of a three-electrode valve. Results are shown in Fig. 2, and on analysis give $\mu = 18$, $R_a = 30\,000$, $P\left(= \frac{1\,000\mu^2}{R_a}\right) = 10{\cdot}8$—the latter being an exceptionally good value.

Lastly, as in this circuit the plate circuit is used as a rectifier, the current in it was tested against plate volts, each curve for different voltage on outer grid. The results in Fig. 3 show that the rectification is quite good, so that the valve should function very well in such a circuit.

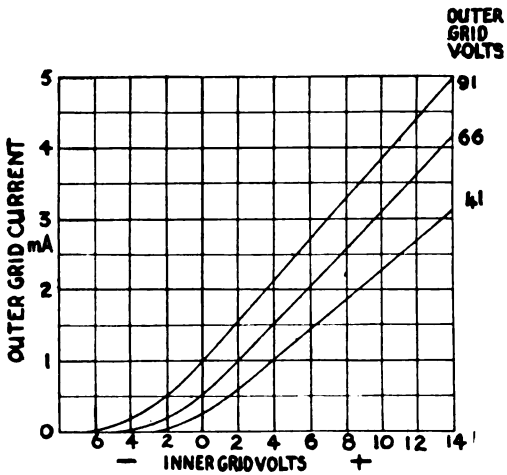

Fig. 2.

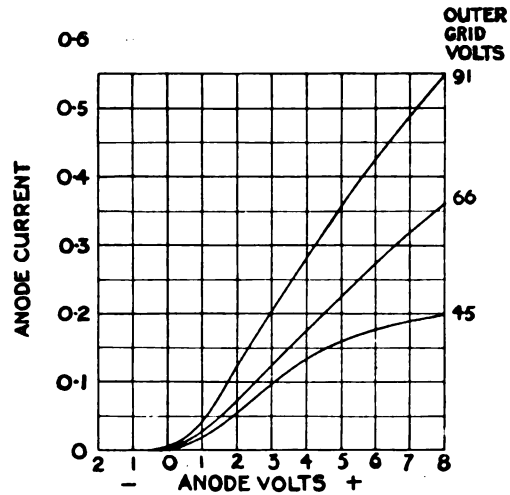

Fig. 3.

ESPERANTO FOR WIRELESS.

The necessity for the international adoption of an artificial language was particularly apparent during the past year, when amateur experimenters in one country succeeded in getting into communication with amateurs of another but found themselves debarred from intelligent conversation by linguistic difficulties. It is believed also that international communication by amateurs will become even more popular during the coming year, making the adoption of an international language imperative.

This point was long ago recognised by the American Radio Relay League, and after a thorough survey of the situation they have, with certain qualifications, decided in favour of Esperanto as its official international auxiliary language. This decision was reached on the ground that Esparanto is easily the chief of the artificial languages, having by far the greatest number of followers.

In order not to come to too hasty a decision, the League first communicated with all the national amateur radio societies of the world, and all of these that expressed an opinion in favour of an artificial language strongly recommended Esperanto.

In making public its decision, the League states that it does not regard Esperanto in its present form as necessarily a language that should come into world-wide recognition unchanged, and that it is prepared to adopt such modification of Esperanto or whatever other language may be agreed upon by an authorised international agency. The League believes it essential to the eventual success of an international language that some language of this kind becomes a world-wide working vehicle of expression, after which authorised agencies can make such rectifications as may then seem desirable.

INDUCED CURRENTS CAUSE EXPLOSION.

That wireless waves can and do produce charges of electricity in certain pieces of iron which discharge as small sparks, is the reason advanced by General Negrei, Director of the Technical Department of the Roumanian Army and Professor of Bollastics of the Bucharest Military School, for many of the hitherto unexplained disastrous explosions.

The theory is that wireless waves produce slight electric charges in such objects as iron rings broken by a small cut and not attached to or in connection with the earth. Stated plainly, these iron rings act as " condensers " to store the small amount of energy radiated by various wireless stations—actually the reception of energy by induction. The action of such wireless waves in producing induced current in iron rings is probably greatest at the meeting point of two series of wireless radiations. Under ordinary circumstances this energy would be of no serious consequence, but after a long period of charging, if a sufficiently small distance between the condenser and the ground was found, the ring would discharge its load across the intervening space by means of a tiny spark. The potential destructiveness of this spark in the event of explosive material being in the vicinity is obvious.

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G.2KW. An Amateur Station.

AMATEUR radio is making such rapid progress day by day that one feels somewhat chary of discoursing at any length on apparatus made or experiments performed; yet in order that real progress shall be made it is necessary for one to become acquainted with the groundwork done by others. It is, therefore, my intention to make a few remarks on the apparatus that was used at 2 KW last winter for long-distance working.

When first acquainted with the possibilities of short wave amateur communication over great distances, it seemed as though the inclusion of several stages of radio frequency amplification was a necessity. Last winter two or three radio frequency valves were almost continuously used. Now and then signals from U2ZL and from U2CPD and the louder Atlantic coast stations were received on one and two valves, but no great effort was made to attempt regular reception with such a set. From September 5th, 1923, no radio frequency valves have been used. The set is a two-valve combination, consisting of rectifier and one stage of low frequency magnification. Whilst the addition of high frequency valves might be highly desirable, a tuned amplifier is hopeless for quick searching. We await the indication of a method of direct radio frequency amplification on low wave-lengths which will be flexible.

I am frequently asked to pass an opinion on a particular set which does not seem to be giving the results that might be expected of it. The workmanship may be beyond reproach, the materials used most expensive, yet the results are poor. The main reason for this seems to be that there is far too much material in the set. Some, though by no means all, of the super and reflex circuits form very good examples of this type of set. With shoals of switches and all the necessary wiring one would hardly imagine that the affair would be either startlingly stable or extremely efficient.

Coils preferably wound on air with single wire—not stranded—would be approaching the ideal. This would apply to transmitting coils as well as to receiving inductances. If a former is used, give ebonite and all other fancy preparations the go-by, for the loss is greater with a coil wound on ebonite than it is with a coil wound, say, on the much despised and common cardboard.* Coil holders are regular beehives of dielectric loss. Choose one with as little material in it as possible and try to think of it as an instrument rather than as a piece of furniture. It is as well to keep this fact solidly fixed in your mind: that in all our tuning circuits we are dealing with high frequencies. It is, therefore, absurd to consider only the D.C. insulation, for in so doing we are apt to forget altogether about the very much more important radio frequency component which we must cherish as carefully as we can.

Variable condensers should be designed to have as low a minimum capacity as possible. There should be no switches in high frequency circuits. All leads should be as short as possible, round wire or thin varnished copper tubing being used for wiring-up. Solder all connections carefully, removing any surplus "flux"; it is best to use resin. When choosing a low frequency transformer it is as well to remember that infinite insulation between the winding is not required. Instead, the windings should be designed to stand up reasonably

* It will be understood that these are our contributor's personal opinions. (Ed. E.W. & W.E.)

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on ordinary voltages. I have found that transformers tested to 2 000 volts between the windings have burnt out when the anode voltage in use was only 50. This state of things is ridiculous. Many experimenters continue to use high resistance phones. I cannot understand why, for

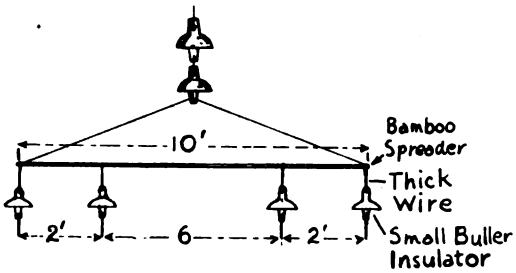

Fig. 1.

signal strength with 120 ohms Brown's A type phones with a good telephone transformer is all that can be desired.

We are now exploring the band of wavelengths from 90—150 metres, and it has been noticed that fading is practically non-existent. Signals on 100 metres are heard when signals on 200 are either absent or very weak indeed. On many occasions G.5KO has been QRZ at 2KW on 200 metres, but on 150 metres the strength increased enormously and remained practically constant. I do not think that it is merely because the radiation of the transmitting station increased, but rather that for some obscure reason there is a sort of "barrier" between the two stations. G.6RY behaves similarly, whilst difficulty is experienced in this district with the reception of Cardiff.

Though many experimenters have an idea that a low aerial is better for reception than a high one, my experience points to the contrary. The aerial at 2KW is 70 feet high at both ends. The masts are 90 feet apart, the actual aerial being 50 feet long with a 35 feet downlead. At present, of the four-wire type, the aerial wires are spaced on 10 feet bamboo spreaders, the distance between the two inside wires being 6 feet. As the current in the aerial tends to flow on the outside, this arrangement was thought best.

Very careful attention has been paid to insulation. Low capacity insulators made by Messrs. Buller's, Ltd., 7, Laurence Pountney Hill, London, are used. These are real insulators for the transmitting amateur, and the old bits of pot generally used should give place to something of the kind. Fig. 1 shows a suggested method for the spreader. The question as to whether stranded wire is better than a single wire is, I know, a vexed one. On the whole it would seem advisable to leave stranded wire out of one's calculations, because the doubtful advantage to be gained is negatived if one wire is left disconnected. The lead-in is a four-wire fan and will be taken through a special porcelain insulator mounted in a plate-glass window in the wall. Arrangements are being made for this very necessary alteration.

The counterpoise or earth-screen, at present in the form of a fan, consists of eight wires 60 feet long. The lead-in is an eight-wire cage, the wires being spaced with aluminium hoops 1 foot in diameter. The wires are supported at the further

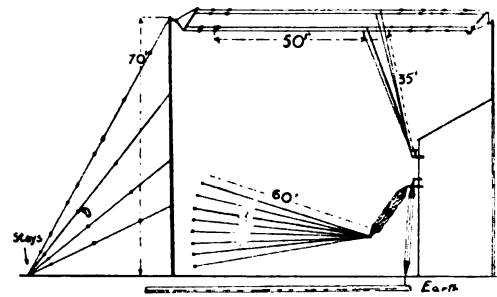

Fig. 2.

end by means of two clothes-props, accidentally acquired in the cause of science! The area at present covered by the counterpoise is approximately 500 square feet, about 700 feet of No. 18 S.W.G. hard drawn copper wire being utilised. A six-wire cage serves to connect the wires buried underneath the aerial with the set. Bunching of wires should always be avoided where radio frequency currents are being dealt with. After the many weeks spent last summer in laying wires three feet in the earth I have found that the results as far as transmission is concerned are very poor. Reception on counterpoise is also quite as good as with the earth and results are constant. The earth is used for transmissions on rare occasions and even though the counterpoise is used as an "earth-screen" very poor efficiency is obtained. Fig. 2 shows a sketch of the radiating system.

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The change over switch is mounted on two ebonite rods, thus reducing its capacity to earth. The transmitter is connected up as indicated by Hartley, inductive coupling of the primary and secondary circuits being used.

Whilst being an excellent circuit for low impedance valves and an aerial circuit of low resistance, the circuit is not nearly so popular here as in America. I have found that with proper adjustment one could wish for nothing better. Two Mullard type 0/150 valves are used normally, though they are temporarily out of commission. The writer has obtained excellent results with them as well as with the Mullard type 0/20 valve, for lower power work.

The present circuit diagram is given in Fig. 3 together with values of condensers, etc. It is quite possible to use an Auto-coupled Hartley circuit, though considerable difficulty has been met with at 2KW when testing with this arrangement. Interference was caused by harmonics, key-clicks and other forms of frightfulness calculated to strike terror into the heart of a B.C.L. The lower diagram on Fig. 3 shows the method of keying.

A Sullivan hot-wire meter reading 0—10 amps is used for observing changes in aerial current. I will put it that way because a hot-wire instrument can very rarely give an accurate reading at the high frequencies used by the amateur.* The goal of most of us seems to be to wreck the instrument by sending the needle off the scale. The fact that one is obtaining an aerial current of 10A does not of necessity prove that the aerial amps are being used to the best advantage. It may happen that there is an iron roof or some other metallic body in the vicinity tuned to the transmitting wave-length. It is not even sound practice to ask for reports, because they are always so conflicting. The only sure remedy is to find out something of your aerial characteristics before you camp on any definite wave-length.

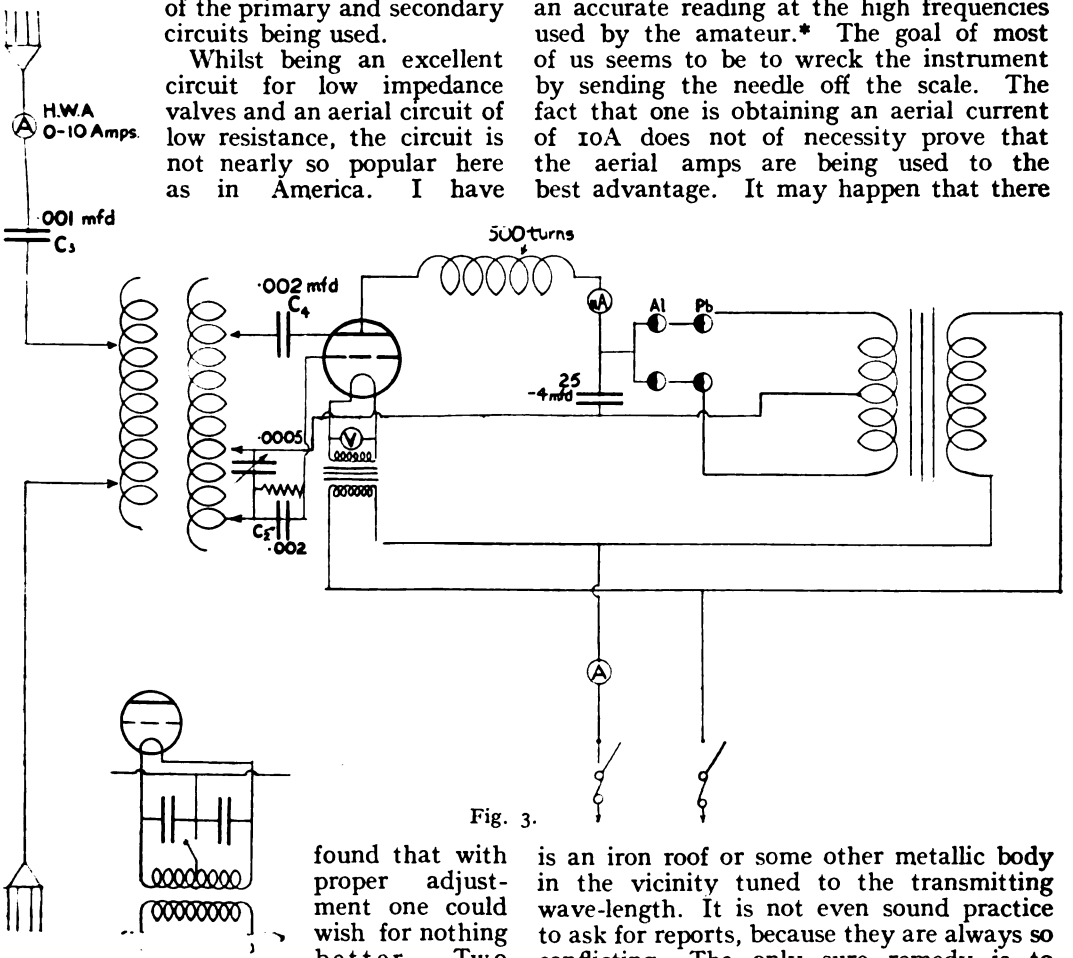

Fig. 3.

The two inductance coils are wound in the form of a spiral on ebonite arms. The aerial coil consists of 17 turns, there being 27 turns on the closed circuit coil. Copper strip ½ inch wide is used instead of wire, the spacing being $\frac{7}{16}$ inch between the turns. Contact to these inductances is made by means of special clips. All such contacts are at present variable. The condenser C_1 is of the order of ·0005μF.

* Unless carefully placed at a voltage node in the aerial. (Ed. E. W. & W. E.)

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C_2 is a Dubilier, type C.D. 158, tested to 5 000V. C_3 consists of two type 577 Dubilier condensers of ·000 5 μF. each, connected in parallel and placed in series with the aerial for 100 metre work. C_4 is home made. An ex-army 1μF. condenser was taken to pieces and the mica (·002 inch thick) carefully examined. Seven sheets were fastened together to form one sheet of dielectric for C_4. Trouble was experienced with other condensers, as they had a nasty habit of breaking down. This condenser should be tested to a voltage of five to ten times the applied D.C. voltage, so that it may stand the radio frequency potentials across it. The actual voltage to which this condenser will have to be tested to fit a certain set of conditions may be easily calculated. The grid-leak, of Zenith manufacture and tapped in values of resistance from 1 000 to 20 000 ohms, is of the vitreous type. The higher the grid-leak value within limits, the greater is the efficiency of the set, because the input current is reduced. When a filter is used the A.C. component is much weaker with a grid-leak of high resistance.

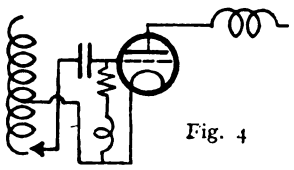

Fig. 4

Sometimes it is found advisable to connect the grid-leak as shown in Fig. 4. Though not practicable in the Colpitts circuit, both the Hartley and the 1DH circuit may be altered in this way. It is claimed that the current in the anode circuit is reduced and the aerial current increased. Assuming that the grid-coil in the 1DH circuit is tuned and the grid-leak connected across the grid-condenser in the ordinary way, we find that the grid-coil is acting as the tuned choke at the same time as it is functioning as the tickler coil. It is therefore difficult to see how any definite advantage may be gained by making the alteration with the 1DH circuit.

Now, in the Hartley arrangement, things are slightly different, for if the grid-leak is placed directly across the grid-condenser then the portion of the coil between the grid tap and the filament tap certainly is not tuned to the working wave-length. Thus it would seem that the use of a separate choke and condenser with the Hartley circuit would be an advantage, but with the 1DH circuit no definite advantage would be gained. We might still prefer to tune the grid portion of the coil in Fig. 4 with a variable condenser and so again present a similar state of affairs as in the 1DH circuit (Fig. 5).

The anode choke coil is a lattice wound affair of 500 turns of 26 S.W.G., D.C.C. wire. After winding, the coil was placed in a warm oven for some time to dry thoroughly. Upon being taken from the oven it was immersed in liquid paraffin wax and allowed to cool and set hard. Next the coil was cut out of the wax, and after being bound up with empire tape it was mounted in position.

The filament rheostats are wound with No. 16 S.W.G. bare resistance wire and the springs mounted on special fibre formers. It would be better to regulate the brilliancy of the filaments by means of either a choke or resistance in the primary circuit of the transformer.

Besides the aerial ammeter, which is by no means the most essential instrument, voltmeters reading 0—15 volts are provided for observing the exact potential across the filaments (V). An ammeter reading 0—10 amps is placed in the main supply so that the exact current may be known. This was found of high importance when using the chemical rectifier. A G.E.C. 0—250 milliammeter indicates the current in the anode circuit. This meter is most essential, for by it the efficiency of the set may be determined. A meter reading 0—50mA. is provided as a means of indicating the grid current.

It will be noticed that power from the transformer is conveyed to the anodes of the valves by the parallel method of feeding. The circuit is so arranged that the risk of burning out the filament transformer is minimised. By using the series method of feed, great R.F. strains are put on the windings of the filament transformer with the result that blue smoke issues from the transformer and bad language from the mouth of the irate experimenter.

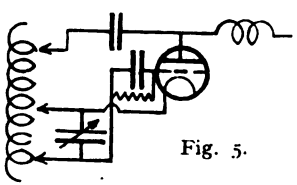

Fig. 5.

The power transformer is of home construction. The iron laminations are in the form of L pieces. The formers for the wire

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are made with thin leatheroid or presspahn, ebonite flanges being glued to one end; the other end piece is fitted, but left unglued so that the sections may be slipped on. The best way is to make a wood former the size that the core is to be when built up. When all is set, the former with one bobbin on it is mounted in the lathe. Half the primary turns, 600 in all, are wound on, each layer being insulated with varnished silk. Adhesive tape is next bound round the coil and then mica sheets are fastened down all over the surface of the tape. A little cotton will hold the mica in place and sheet after sheet may be put on while the cotton is wound round to hold them in position. I have nearly $\frac{1}{8}$ inch mica between the primary and secondary windings. These operations are repeated with the other bobbin. The secondary of the transformer is wound with 4 000 turns of No. 26 S.W.G., D.C.C. wire, as this gauge will allow of overloading the transformer to a certain extent. Instead of winding the 4 000 turns on in one piece, ten sections are wound consisting of 400 turns each. They are $\frac{3}{16}$ inch wide. A former was made with a perimeter equal to that of the primary bobbin. After rigging up a bath of paraffin wax with a Bunsen underneath it, the wire is passed under a brass rod fixed beneath the surface of the melted wax. The level of the wax is kept just high enough

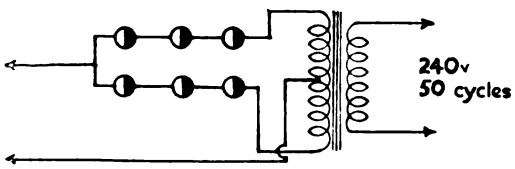

Fig. 6.

to allow the wire to run through it. After numerous unsuccessful attempts the operation was a complete success.

When sufficient sections have been wound they may be built up, care being taken to connect the windings in the same sense as the primary. In connecting up the sections it is advisable to place between each a piece of varnished silk or some other insulating material, such as micanite. When both coils have been built up in this way, the flanges are glued on and, when set, the iron laminations may be put into place. The transformer in question has, at present, enough secondary turns to give only 1 300V, after allowing for the potential drop in the rectifier.

One bobbin has also itself a centre tap so that either half or full voltage may be obtained. This is a great advantage as the same transformer may be used for low power work. Whilst not ideal in many respects this method of construction seemed the simplest at the time.

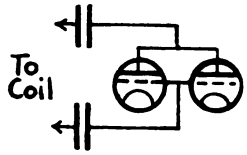

Fig. 7A.

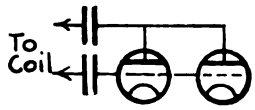

Fig. 7B.

The filament transformer is built up in the same way, it being capable of giving a current of 10A at about 12V. There are 3 000 turns of 26 S.W.G. D.C.C. wire on the primary and 150 turns of No. 12 D.C.C. wire on the secondary. Had the supply of iron been unlimited at the time much more would have been used, with the consequent reduction of primary turns. A centre tap is provided both on primary and secondary so that condensers of ·02μF. (which are two (·01 mfd.) type 577 Dubilier condensers connected in parallel) may be connected across the two halves as a protection device. Keying is accomplished as shown. It is always as well to see that the portion of the key nearest the operator's hand is at earth potential. I am not in favour of keying in the primary lead of the power transformer, for sudden surges are liable to be set up by this means. It may happen that "key thumps" are inflicted on your neighbours. Assuming that some effort has been made to render the note of the C.W. variety, these are most annoying. Not only on the proper wavelength, but over a range of hundreds of metres do they bang into one's ears. This is at present one vital reason why transmission on the low waves is impossible during broadcast hours.

With both valves in use, taking an anode current of a 120 to 150mA, the aerial current on 170 metres is 4 to 5A. When on 115 metres the aerial is around 2·5A, but on occasions it has reached 4A. At present with one 100W valve the aerial current on 120 metres is 1·5 to 2A, and on 170 to 190 metres 3 to 3·5A. Consequently,

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considerable increase is expected when the two valves are again put into use on full voltage. With one 0/20 the aerial current is 0·4A on 120 metres and nearly an ampère on 170 metres, this on an input of 10 to 15W.

The rectifier for converting the 50 cycle supply to D.C. is of the orthodox electrolytic type. Built on the lines of Mr. E. H. Robinson's collection of cells, but designed to pass a heavier current, the thing has up to now given very good service. Mounted on an insulated floor with a low capacity to earth are forty cells, twenty in each leg, of the high tension leads. The aluminium has a submerged area of 40 sq. cm., as also has the lead. Pickle and jelly jars are used to hold the electrolyte, which is a half saturated solution of pure ammonium phosphate. About 4 lb. of the salt were used for 50 cells. Distilled water was not used, as the town water is fairly pure

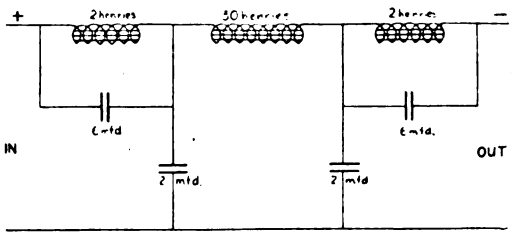

Fig. 8.

Great care was taken in the cleansing of the electrodes.

I do not think that sufficient attention was paid to the nitric acid bath. With some aluminium strips this bath was omitted, with the result that they had to be recleaned. Upon putting a few hundred volts across the rectifier the needle of the ammeter in the primary circuit did a war dance. By using the switch as a kind of tapping key for a few moments the current was reduced to two ampères. Left running for a few minutes it dropped to ·5 ampères. After two days it was noticed that some cells refused to rectify, but there are no refractory cells. It should be pointed out that when a centre-tapped transformer is used the connections for the rectifier are as in Fig. 6. In Mr. Robinson's article we see that the positive lead is taken from the centre tap. This is obviously the negative lead. Each night before actual transmission is commenced it is advisable to cut down the voltage across the transformer and turn on the current for a moment or two. The rectifier passes a good many ampères for a few seconds, but the current quickly drops. The set may now be put into operation. For this reason I fail to see the point in carefully "forming" the rectifier when first put together because it seems to require "forming" every night.

When preparing to transmit, turn on the filaments, next the high tension. When preparing to listen the H.T. should be switched off first, then the filaments—gradually. The rheostats shown in the diagram are for final adjustments only. All connections should be soldered and made as short as possible, the high frequency circuits being wired with copper tubing. Make the filament leads of very thick wire, placing the condensers as near the valve terminals as possible. If two valves are to be used in parallel it has been found that on occasion no addition is made to the original aerial current obtained with one valve. The chief cause for this is probably that the grid leads are of different lengths and so the valves are not pulling together. Fig. 7A shows the proper way of connecting the grids together, while Fig. 7B shows the wrong method. Upon adding an extra valve to a single valve transmitter the aerial current should be increased by 50 per cent.—and the power in the aerial doubled. By the way one does not radiate amps!

The filter, or smoothing unit, has not yet been constructed, but will take the form shown in Fig. 8. It is a combination of the "Brute Force" type and the more scientifically designed one. The 2μF. condensers are tested to 5 000V D.C. and the 6μF. condensers may be tested to a lower potential. At present 1 of 4μF. has been used across the line with pretty fair results. When operating on 100 metres I have noticed that the smoothing effect is very greatly reduced.

G.2KW has been heard on three continents; Europe, Africa and America, reported with code verified in the recent tests; signals were logged by WNP, 1BCF, 1ANA (one valve), 1BDT and since by a number of stations, including some in the fourth, fifth and ninth districts. Two-way working has been effected with 1KC and 1CMP, 1AJA and 1XAH. Through circumstances over which I have had no control, the operating hours of 2KW have been somewhat limited, and that is why more stations have not been worked.

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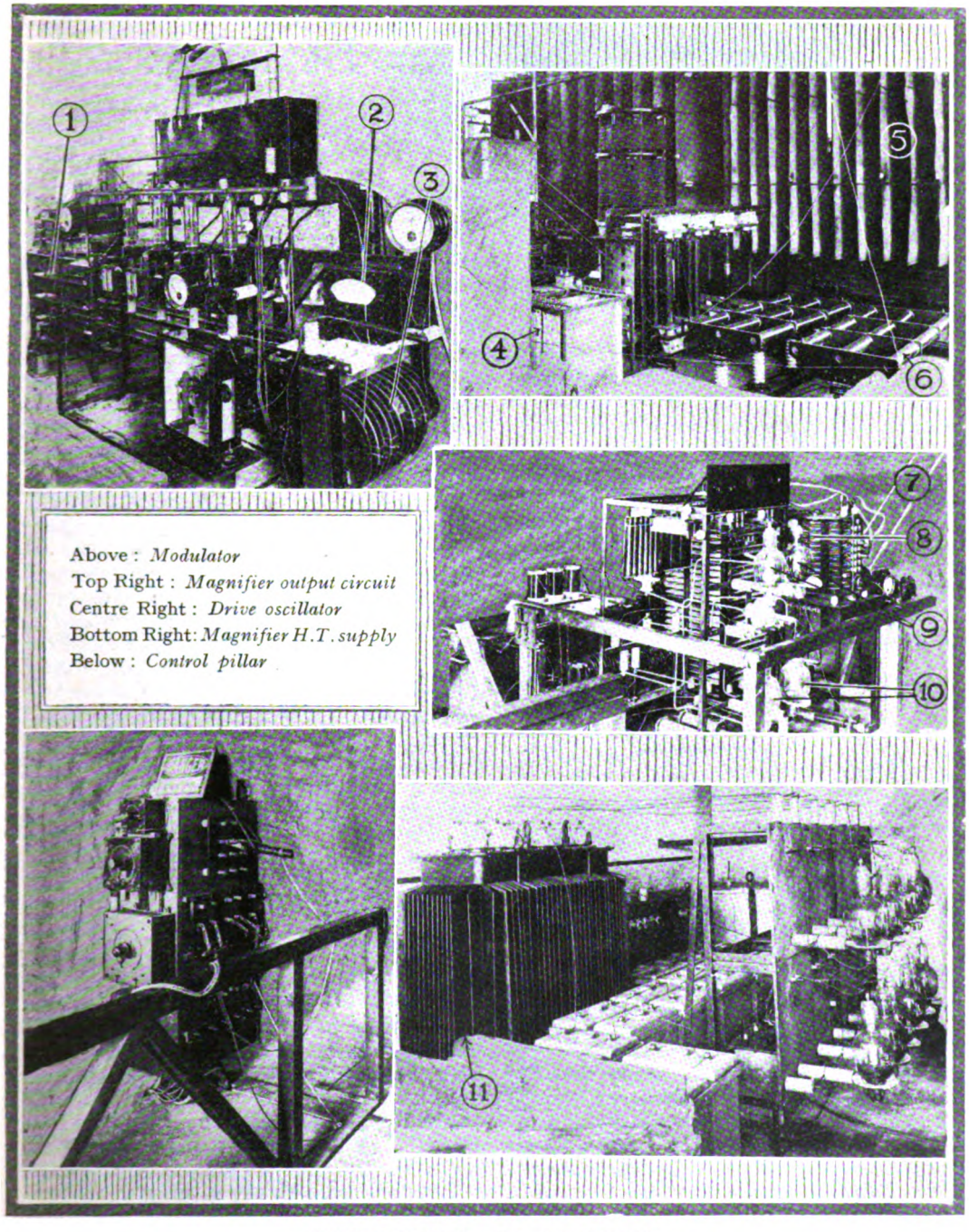

Above : *Modulator*
Top Right : *Magnifier output circuit*
Centre Right : *Drive oscillator*
Bottom Right: *Magnifier H.T. supply*
Below : *Control pillar*

CHELMSFORD IN SECTIONS.

The following is a key to the reference number :—

1 *Modulator grid battery*
2 *Modulation meter*
3 *Speech choke*
4 *Magnifier grid-leak*
5 *Main output condenser*
6 *Magnifier H.F. choke*
7 *Drive output leads*
8 *Drive coupling coil*
9 *Drive oscillator valves*
10 *Drive rectifier valves*
11 *Magnifier H.T. supply Transformer*

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Valve *v.* Crystal for Detection.

By P. K. Turner. **[R149**

IT is a curious example of lack of imagination that apparently 95 per cent. of the valve sets in use to-day for broadcast reception utilise a valve with grid-condenser and leak as detector, although this method of rectification is notorious as an almost certain cause of distortion.

It seems that this is an opportune time to try and show, in as simple a manner as possible, why it is that this method of detection is so prone to cause distortion.

For the sake of completeness we will begin by stating the action of a valve used for grid rectification, although our readers are, of course, familiar with it. The connections are as in Fig. 1, and the action is as follows: Before the arrival of signals the grid sets itself to a slightly positive potential, such that the grid current passing is exactly that which the difference between the voltages at the grid and the point A will push through the leak. Thus, if the valve gives 1 micro-

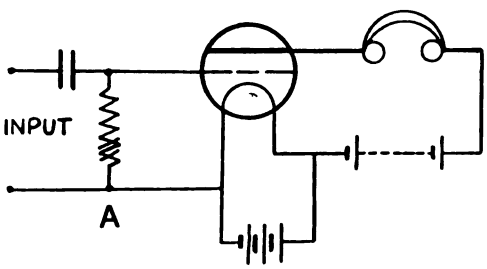

Fig. 1.

amp grid current with the grid 1 volt positive, and a 3-megohm leak is connected to the + side of the 4-volt battery, the grid will set itself at + 1 volt, when we shall have 4—1=3 volts to push current through 3 megohms: obviously this is a stable condition. Now when the first positive half-cycle of H.F. is applied to the grid-condenser, the grid will be made more positive for a short time; there will be on increased grid current flow, and the grid and grid-condenser will be *negatively* charged. If the incoming wave is like Fig. 2a, the grid and condenser will get, *owing to the grid current*, negatively charged up according to Fig. 2b, so that its total voltage, from incoming signal and grid current, will be as Fig. 2c.

During the negative half-cycle there is no grid current, nor during the first part of the next positive cycle, so that the grid voltage will vary as shown in Fig. 3a, in which Fig. 2c is repeated. But directly the total volts reach the original free value, grid currents again flow faster than the leak can deal with them, and instead of the dotted curve at the end of Fig. 3, the grid gets more negative, as shown in the full line.

The net result is the well-known curve of Fig. 4, showing (*a*) grid voltage, (*b*) the low-frequency component of anode current.

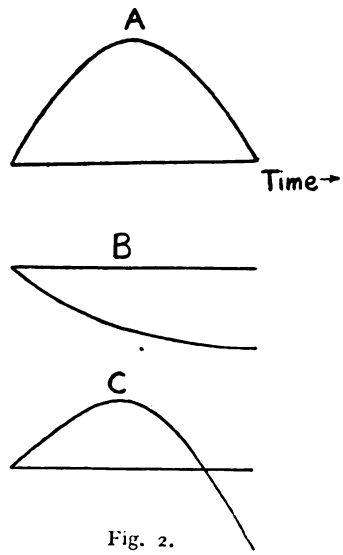

Fig. 2.

These are for a steady carrier wave. If now the incoming signal stops, the extra charge leaks off the grid, and the plate current returns to normal.

So far we have said nothing that is not absolutely familiar. Now note that although we have represented the signal as coming on suddenly, the change of plate current occurs gradually, as the grid gets charged up little by little. What controls the rate of charging up? Firstly, the amount of grid current the valve passes at any given grid voltage; secondly, the size of the grid-condenser. For, given a certain amount of grid current for a certain time, the voltage depression depends absolutely on the size of condenser: for example, if the average grid current for the half-cycle is 1 microamp, and the half-

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cycle lasts a half-millionth of a second, then

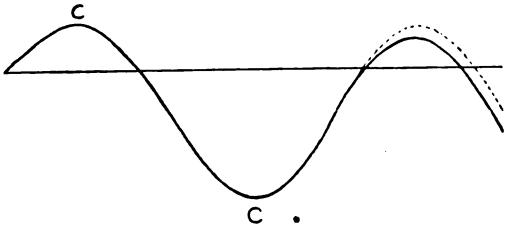


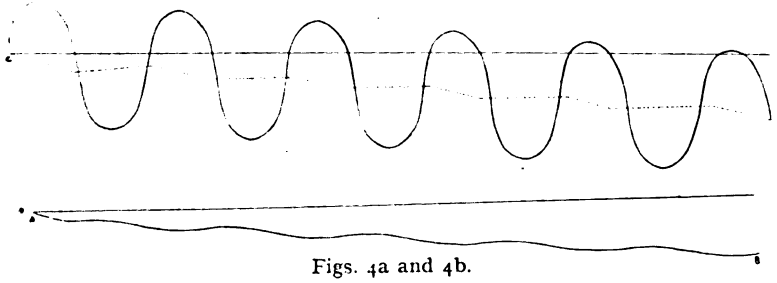
Fig. 3.

if the grid-condenser is of ·0002μF, the voltage will drop $\frac{1}{400}$ volt: if the condenser is ·0001μF, the drop will be $\frac{1}{200}$ volt.

This shows us that the shape of the first part of the plate current curve—its fall from normal—depends on the valve and grid-condenser. Similarly when the input is a modulated current, as in telephony, the shape of the plate current curve as regards its falling part (A B in Fig. 4b), does not depend only on the shape of the incoming wave, but also on the valve and the leak. If the wave is shaped as in Fig. 5a, the plate current should be of the shape of the full line in 5b; but according to the condenser and valve it might be shaped quite differently —like either of the dotted lines for example.

Secondly, as regards the remainder of the plate current curve, after B in Fig. 4a. This again depends, not on the shape of the signal current, but on the condenser and the leak. The larger the condenser and the leak, the longer it will take for the grid volts and plate current to return to zero.

An actual example of the effect is shown in the curves of Fig. 6, taken from Morecroft's *Principles of Radio Communication*. These are actual experimental curves, identical except that for curve 6 (c) the grid-leak was about three times that used for 6 (b). The actual incoming signal is shown at (a).



Figs. 4a and 4b.

Bearing in mind that any difference between the outline of the incoming signal and that of the plate current *is* distortion, we are forced to the conclusion that grid detection is a totally unsatisfactory method. Even if, by chance or skill, a variable grid-leak and condenser are adjusted to give the right shape for a note of (say) 1 000 audio frequency, they will be wrong for any other.

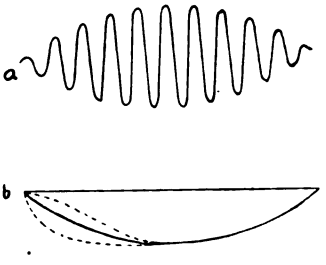


Fig. 5.

But before turning to other methods as superior we must examine them also. As it happens, the other two available methods —crystal detection and "plate rectification" by a valve—are essentially similar, and can be investigated together. It will hardly be necessary to recapitulate the action of the crystal detector: we will confine our attention to considering its response to signals of various strength, which is easily shown to be the criterion as to distortion. It is very commonly stated that the characteristic curve of the crystal is such that the output varies as the square of the signal strength; *i.e.*, a signal of half strength is reproduced as a note of quarter strength. This is approximately true for weak signals, but is not so for strong ones.

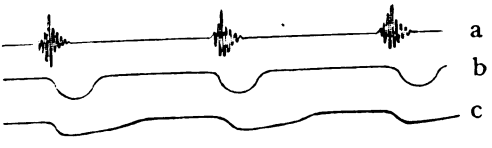


Fig. 6.

Take for example an imaginary crystal such as that whose curve is shown in Fig. 7: there is no reverse current and a constant resistance. It is easily seen by scale drawing that the output is proportional to input. But with a curve such as Fig. 8, the "square" law is true (with a good crystal the "reverse"

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current is negligible in either case). Now, the curve of an actual crystal is in the majority

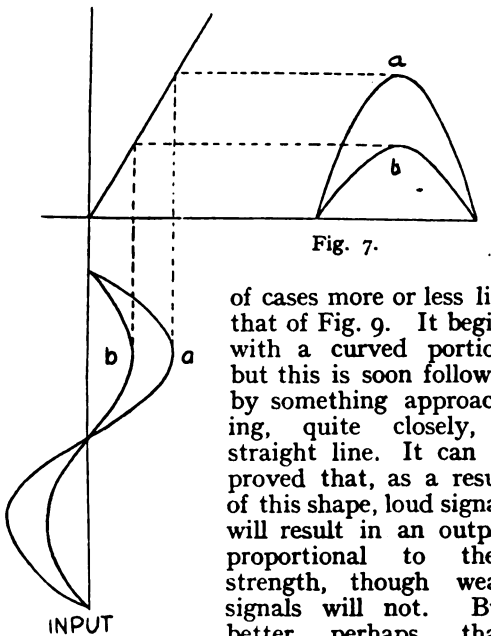
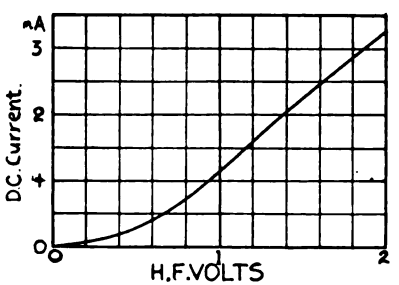


Fig. 7.

of cases more or less like that of Fig. 9. It begins with a curved portion, but this is soon followed by something approaching, quite closely, a straight line. It can be proved that, as a result of this shape, loud signals will result in an output proportional to their strength, though weak signals will not. But better, perhaps, than mathematical proofs are experimental results, and we have again drawn on the invaluable Morecroft for Fig. 10, which shows the telephone current produced by a given H.F. input. It will be seen that for all inputs greater than about ·5 volt the graph is practically a straight line, and there



will be no distortion due to the detector. This curve was for a Penikon detector of high resistance: we shall not be far wrong in assuming that for a galena we could depend on the absence of distortion for inputs greater than about ·2 or ·3 volt.

Lastly, what about using a valve with plate detection, *i.e.*, no grid-condenser? This is easily dealt with by remembering the general appearance of a valve characteristic. The bend at the foot of the curve is by no means sharp, and the minimum input to avoid distortion is

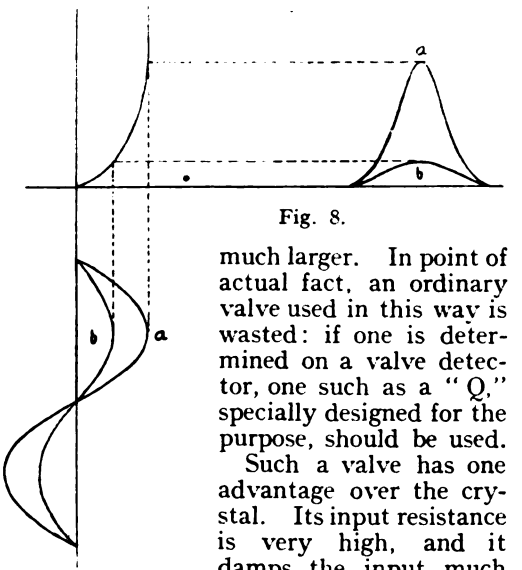


Fig. 8.

much larger. In point of actual fact, an ordinary valve used in this way is wasted: if one is determined on a valve detector, one such as a "Q," specially designed for the purpose, should be used.

Such a valve has one advantage over the crystal. Its input resistance is very high, and it damps the input much less. But, as has been pointed out several times during the last few months, much of the damping effect attributed to the crystal is simply due to using a low resistance crystal in a circuit designed for one of high resistance. The methods suggested by Colebrook and others (recapitulated in *The Perfect Set*, p. 22) avoid this trouble.

Summarising, these are the conclusions to which the writer is forced: perhaps some reader can refute them. They apply, of course, only to apparatus intended for the distortionless reception of music.

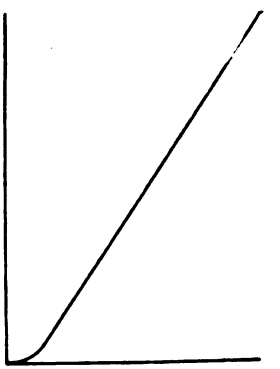


Fig. 9.

(1) The use of grid-condenser and leak is not permissible;

(2) A crystal is the best method;

(3) The input must be made at least ·3 volt (and preferably more) by H.F. amplification if necessary;

(4) Undue damping can be avoided by proper design.

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On Some Properties of Low-Tension Discharge Tubes.

By James Taylor, B.Sc.

In the following article the author considers the volt-ampère characteristics and their practical application, and describes the employment of "Osglim" lamps for the detection of wireless waves.

Abstract.

THE article deals with the volt-ampère characteristics of low-tension discharge tubes and gives an interpretation of the different portions of them.

It is further shown how the peculiarities of the characteristics have been applied practically, in their use as current rectifiers, relays and voltage-transformers.

Some experiments on the use of the "Osglim" lamps for the detection of wireless waves are described.

Introduction.

One low-tension discharge tube at least, in the form of the "Osglim" lamp, is now very well known and widely used by wireless enthusiasts. There are certain properties, common to all gas discharge tubes in which the cathode and anode are not more than a few mms. apart, which are well illustrated in the case of the neon lamp, and make it of use in wireless practice.

When the electrodes of a discharge tube of this type are connected to a potential difference sufficiently high, a discharge passes, and a glow—the so-called negative glow—restricted under ordinary conditions to the cathode, and spread over both sides of it, ensues. It is found that no discharge will occur till the potential applied to the lamp attains a certain value termed the upper critical voltage V_c, but that, if the discharge is once initiated, the potential difference may be reduced to a very much lower value, called the lower critical voltage V_b, before the discharge ceases.

The Volt-Ampère Characteristics.

The volt-ampère characteristics for the tubes are extremely interesting. If a discharge tube of the above type is connected in series with a battery of sufficiently high voltage to drive the lamp, a variable high resistance R, and a microammeter, and an electrostatic voltmeter is shunted across the tube terminals so that the potential across it may be measured, a complete volt-ampère characteristic for the tube may be obtained by progressively diminishing the value of R and taking the corresponding readings of the microammeter and voltmeter (see Fig. 1 for diagram of the circuit).

In the case of the "Osglim" lamps it is necessary to remove the ballasting resistances from the caps before experimenting with them. It is, however, possible at the present time to obtain lamps of this description without the usual ballasting resistances in their caps (they are made specially for

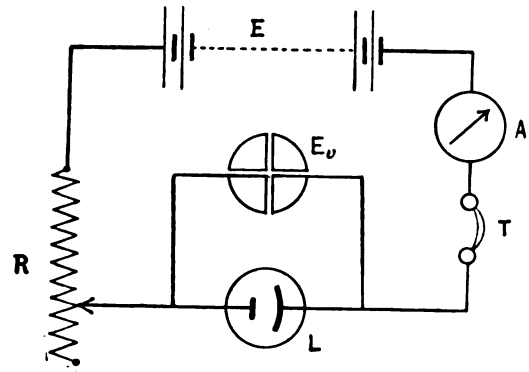

Fig. 1.

wireless purposes). The ordinary 240 volt mains provide a convenient voltage for driving the lamps, but it is preferable where possible to use a battery source of potential, free from the voltage fluctuations which almost always occur on main supplies.

The resistance R may conveniently have the initial value of one or two megohms.

When the complete volt-ampère characteristic is determined it is found to be of the general form shown in Fig. 3 (the current scale of the portion A to D is magnified for the sake of clearness). It comprises several distinct portions as shown.

If a telephone is included in the circuit, it is found that when conditions correspond to the portion of the characteristic to the right of E, the current is regularly intermittent in

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nature, and gives rise to a high note in the telephone. From E onwards to the right the characteristic is negative, that is a *decrease* of the voltage across the lamp terminals gives rise to an *increase* in the current through the lamp.

The present writer regards this regular intermittency of the discharge tube current as, purely and simply, a manifestation of the ordinary "flashing" phenomenon of the lamp. It ought to be mentioned here that this view is not generally held.

The "flashing" of the neon lamp is well known and has been described in a previous issue of this journal,* so that it is not

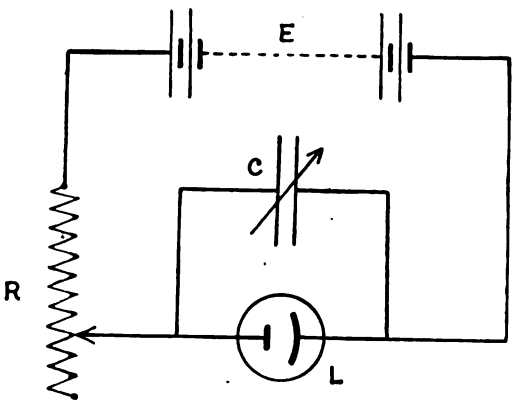

Fig. 2.

necessary to enter into the matter very fully.

When a capacity C is shunted across the terminals of the tube, and it is connected through a high resistance R to a source of voltage E (see Fig. 2), a regular "flashing" or lighting up of the lamp occurs at intervals, the time of flash, or more correctly the time taken for the condenser to charge up from the lower critical potential to the upper critical potential and to discharge through the lamp down to the lower critical potential again, being directly proportional to C and to R.† As the value of the capacity is diminished the time of flash becomes less, and the series of periodic clicks, as heard in the telephones, merges into a low note, which increases in pitch with decrease of C, until finally in some cases the pitch of the note increases above audible frequency.

It is therefore extremely probable that the regular intermittency of the current through the lamp, corresponding to the part of the characteristic to the right of D, is a limiting case of the ordinary flashing with C and R in circuit: C being due to the residual capacity of the circuit leads, the electrodes, and the electrostatic voltmeter.

It is apparent, then, that the voltage across the tube, as measured by the electrostatic voltmeter, is merely the average voltage over the whole time period of flash and charge, and the current is the average current over the period.

This view is supported experimentally by several facts. There is a portion of the characteristic curve from B to C where the voltage is almost stationary with change of current: the voltage at this part of the curve is evidently the limiting average voltage over the whole period, when the time of charging of the circuit capacity becomes great compared with the time of flash or luminous period.

To the right of this portion the energy transference through the lamp becomes very small, since R is large, and the telephones indicate a grating irregularity of flash. Beyond this again the current becomes regular but the discharge is non-luminous (the ordinary Townshend current in gases).*

As the circuit resistance is decreased, the characteristic is traversed from A towards D: there is no discontinuity, the voltage decreases continuously as the current is increased by reduction of R, and the note in the telephones rises in pitch. At the point D, however, a discontinuity occurs, the note in the telephones falls somewhat and then terminates abruptly, the current through the discharge tube becomes steady, and the voltage across the terminals falls in value (by as much as 20 or 30 volts in the case of some discharge tubes in which the filling gas is air, but usually less than this).

At this point the area of the electrode illuminated by the cathode negative glow becomes considerably less, but the intrinsic luminosity is much greater. The current through the lamp also increases abruptly by several microampères at this discontinuity point.

* Robinson. EXPERIMENTAL WIRELESS, Vol. I., No. 1.

† Taylor and Clarkson. *Journ. Sci. Inst.*, Vol. I., No. 6, p. 174.

* Shaxby and Evans. *Proc. Phys. Soc Lond.* Vol. 36, Pt. 4, p. 259.

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It has been shown that there is a critical resistance for the discharge tubes, below which no "flashes" can be maintained.

It is easily seen that if the quantity of electricity flowing from the battery E, through the high resistance R, to the lamp terminals, in a certain time, is equal to or greater than the quantity discharging across the lamp in the same time, then no flashes can take place and the current will become continuous in character. The highest value of R, consistent with the maintenance of flashing in the circuit, has been shown to be

$$R_c = \frac{E - V_b}{k(V_b - V_a)} \qquad \ldots \qquad \ldots (1)$$

where E is the voltage of the battery, V_b the lower critical voltage, k the "conductance" of the lamp, and V_a approximately the cathode fall of potential.*

It would appear that the point D is the critical resistance point for the circuit, and that here the current changes abruptly from the periodic to the steady state. Evidently the part of the characteristic between D and E cannot be obtained except fortuitously, since, at D (in the flashing state) the voltage reading is some definite average between V_b and V_c, that is, greater than V_b, and at E the voltage is steady and, as will be shown, is of the value V_b, the lower critical voltage.

When the discharge through the tube becomes steady, the circuit, in accordance with a perfectly general law (the Law of Minimum Potential Energy), will adjust itself to carry the maximum current under the existing conditions. This state is obviously obtained (since the current $i = \frac{E - V}{R}$) when the potential across the tube is as low as possible, that is of the lower critical voltage value V_b. At D consequently, the lamp will adjust its potential and arrive at the point E, so that the potential across its electrodes is V_b.

As was stated above, at E there is only a fraction of the cathode area illuminated and taking part in the conduction of the current through the lamp. Now the "conductivity" of a discharge tube is (under the present conditions) directly proportional to the area of the part of the cathode illuminated by negative glow.

As the circuit resistance is further decreased, the circuit still continues to carry the maximum current $\frac{E - V_b}{R}$, and the tube increases its conductivity to carry the additional current by augmenting the area of cathodic surface utilised in discharge.

From the point E on the characteristic, to the point F, where the full cathode area is employed, the voltage across the tube is of the lower critical value. The extent of this vertical portion of the characteristic is considerable when the tube is of large cathode area—in the case of some air discharge tubes operated at about 480 volts the present writer has obtained a range of as great as 30 milliampères for this portion.

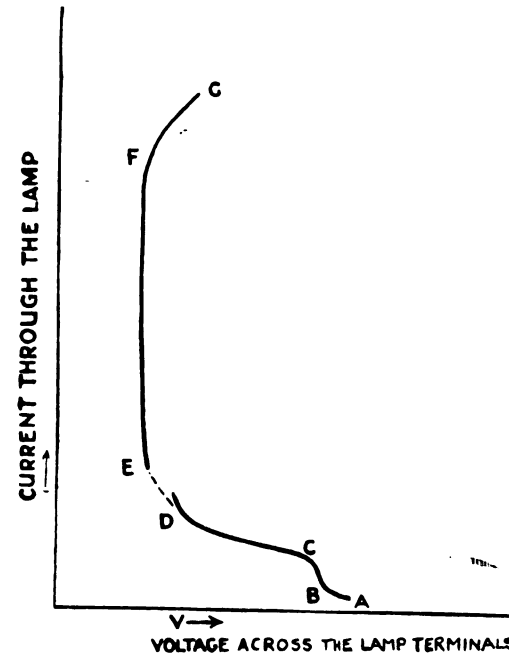

Fig. 3.

At F the slope of the characteristic begins to diminish, and the voltage across the lamp commences to rise steadily.

For this part of the characteristic it has been shown by J. W. Ryde that the following equation holds :—

* Taylor and Clarkson. *Proc. Phys. Soc. Lond.* Vol. Pt. 4, p. 269.

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$$i = \frac{E-e}{\frac{1}{AM}+R} \quad .. \quad .. \quad (2)$$

where A is the area of the cathode, and e and M are constants. The present writer obtained a very similar relation from theoretical considerations.

Practical Applications of the Properties of the Low Tension Discharge Tubes.

Current Rectification and Voltage Transformation.

It may be seen from equation (2) that the conductivity of the lamp is dependent upon the area of the cathode used, consequently if (as in the case of the "Osglim" lamp) one electrode is of large area and the other of small area, the tube will possess the property of unilateral conductivity to an extent depending on the difference of the electrode areas, that is to say, it will pass a much larger current when the electrode of large area is used as cathode than when the electrode of small area is used as cathode.

This property of discharge tubes has been known for a great number of years, and led to their adoption for the purposes of rectification. One of the original uses was for the partial rectification of the high tension current from induction coils. At a later date a variety of these tubes was used commercially, on a limited scale, in Germany, a considerable time before the "Osglim" lamp came on the market. In December, 1915, and later in 1919, F. Schröter published papers on glow discharge tubes.* These tubes had the usual two electrodes, and the filling gas was helium, argon or neon at pressures between 1 and 3 mms.

Fused alkali amalgams were used as cathodes. These metals liberate copious supplies of electrons when bombarded by the positive ions of the discharge, and so possess low cathode falls of potential, which enable the discharge to start at a much lower voltage than normally and give rise to greater currents than those usually obtained. On the other hand, the anode was of iron, a metal of high cathode fall, and no great property of liberating electrons under ionic bombardment: this efficiently prevents any large back current passing when the potential across the electrodes is reversed.

These tubes were fairly efficient in the rectification of alternating current. The efficiency depends, of course, on the material of the electrodes, the effective area of the electrodes, and the filling gas. It is stated in one of the papers that the efficiency in the rectification of alternating current was some 40 per cent. The same author utilised these tubes in connection with the "Problem of Voltage Transformation," for the Hydra Co. of Charlottenburg.

The voltage across the lamp must, under all conditions, be at least of the value V_b, and, as is seen from the graph of the characteristics, the potential will remain at this value over a range of currents represented by the part of the characteristic from E to F. Consequently when the lamp is connected to a high voltage through a resistance, it will subtract a constant value from the main voltage and thus transform down the potential across the resistance to much smaller value.

In a case given by Schröter, there was a potential fall of 190 volts across the discharge tube and of 30 volts across the series resistance. The low voltage circuit, which consisted of a bell, an accumulator, or such like, was placed in parallel with the circuit resistance. "The applications given comprise lighting of signal lamps, ringing of bells, and charging of accumulators."

Notwithstanding this advance, it was still impossible to use such tubes for any purpose where constancy and precision were necessary.

Discharge tube work had, from its very initiation, suffered from grave disabilities which it had not been found possible to overcome. The discharge tubes were always constructed in glass vessels, which were, as a rule, in close proximity to the actual discharge, consequently an accumulation of electrical charge (space charge) on the sides of the vessel occurred and resulted in serious and erratic interference with the normal course of the tube phenomena. Moreover, under the action of the intense bombardment by positive ions, the surface of the cathode became modified in nature, and progressive change of the cathode fall of potential and the conductance of the tube took place.

Lastly, and perhaps the most disturbing effect of all, a "clean up" of the gas in the tube, resulting in a pressure progressively

* F. Schröter. *Elektrot. Zeits.* 36, pp. 677-679, Dec. 30, 1915; also pp. 685-687, Dec. 25, 1919.

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diminishing from the initial value, occurred; this "clean up" is most probably due to the absorption of the filling gas by the electrodes and the glass vessel.

Recently, however, two American experimenters have overcome these disabilities in a most remarkable and ingenious manner, using a principle, known to scientists for many years, and termed the "short path" principle.*

The "Short Path" Principle.

Sir William Crookes appears to have been the first to observe the fact that when two metallic electrodes are placed very near together in a gas at a reduced pressure (so that there is only a few mean free paths of the gas between the electrodes), it is very difficult to get a discharge to pass between them, even at potentials very much higher than those normally required to initiate the discharge. If, however, there are longer paths available between the electrodes, the discharge will take place along these with comparative ease. When only "short paths" are available between the electrodes, they are able, under certain conditions, to withstand voltages of a few thousands before discharge between them takes place.

The Application of the "Short Path" Principle.

The above principle has been applied by Bush and Smith to the production of discharge tube rectifiers; the following may be amplified by a reference to their paper quoted above.

If two cylindrical electrodes A and B, as shown in Fig. 4 are placed in a glass vessel so that no long paths are available, no discharge will pass, even though there is a considerable potential across the electrodes. If now a small hole is made in the electrode B say (see Fig. 5) and B is used as negative electrode, the interior of the cylinder B will now act as cathode and long paths are available for the discharge, so that a fairly large current will flow: the tube is thus free from extraneous influences which cause the behaviour to be erratic. It was found in addition that certain grades of carbon, when used as electrodes, eliminated almost entirely both the clean up effect and the effect due to the modification of the electrode surfaces.

* V. Bush and C. G. Smith. *Am.I.E.E.J.* 41, pp. 627-635.

Tubes of this description with a filling gas of helium at a pressure of 2 mms. and electrodes at a distance of 1 mm. apart, act as very efficient rectifiers of alternating current.

The tube will take currents of many milliamps, on a 500 volt circuit, when operated with the electrode in which a hole is pierced, as cathode, but gives a reverse current of 1·5 milliamps only when subjected to a voltage as high as 1 000 in a reverse direction. The efficiency of the tube as a rectifier is due to two causes. In the first place there is the difference of electrode area. When the pierced electrode is employed as negative electrode, the full inside area of the hollow cylinder is utilised as cathode, whereas in the reverse case the area of the cathode is the much smaller portion of the electrode opposite the hole only.

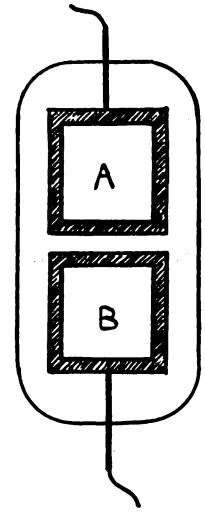

Fig. 4.

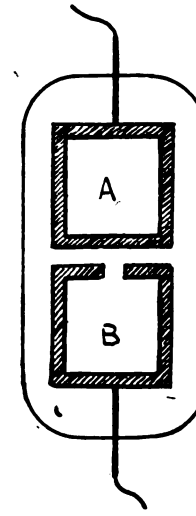

Fig. 5.

This provides a certain one-sidedness of conductivity, but it is not solely, or even largely, responsible for the efficiency of the device as a rectifier. The explanation of the efficiency as a rectifier is found, according to Bush and Smith, in the persistence of the positive space charge within the hollow cylinder.

As is well known, the preponderent part of the potential fall across the tube takes place at the cathode (cathode fall of potential). Consequently when the solid electrode is employed as cathode, the electric

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field within the hollow cylinder will be very small, the motion of the heavy positive ions will be very slow and they will persist over the length of time required for the potential across the tube terminals to be reversed when current of ordinary commercial frequency or greater is being rectified.

In rectification of alternating current therefore, the pierced cylinder when used as anode will act as if it were solid, the paths will almost all be "short" and the tube will conduct hardly at all.

These rectifiers are remarkably steady in their action.

An example is given of one of the tubes carrying a current of 10 milliampères from a storage battery, and the variations in the current were barely audible even when amplified by a two-stage thermionic amplifier.

The above principles were also employed in magnetic rectifiers: these tubes consisted of electrodes in the form of concentric cylinders, built up on the short path principle, so that no current could pass, even though high voltages were employed to effect this.

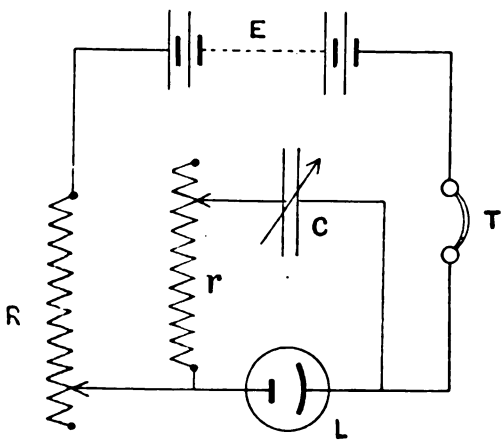

Fig. 6.

A small magnet is attached to the outside of the tube so that the lines of force run along the annular space between the two electrodes. Under the action of the forces due to these lines of magnetic force, the ions of the discharge tube describe curved paths and will thus cease to be "short," consequently a current will flow through the tube. The intensity of the magnetic field required to enable the discharge to start is critical in nature and depends on the diameter of the electrode used as cathode. It is obvious therefore that the magnetic field may be made of such a value that the current will flow only when the electrode of large diameter is employed as cathode. These types of tubes provide very efficient rectifiers and possess the advantage of very long life.

The Anson Relay is another application of the properties of the low tension discharge tube, but it is now so well known as to make a description here redundant.

Application to the Measurement of Capacities and High Resistances.

In a previous article by Mr. Clarkson and the present writer,* a description of the methods for the utilisation of the tubes for the measurement of capacities and high resistances was given, so that a further detailed description is not required.

If a capacity is shunted across a neon lamp which is connected to a charging voltage, through a high resistance, as was previously shown, "flashing" occurs. The time of flash is directly proportional to the magnitude of the capacity and the high resistance in the circuit. These relations can evidently be utilised directly for the measurement of capacities and high resistances.

In the case of very small capacities, a method is employed whereby beats are obtained between two circuits flashing at note frequencies, and the capacities are compared in this way.

Experiments on the Use of the Neon Lamp for the Detection of Wireless Waves.

In some early experiments on the flashing of discharge tubes, the writer made use of a circuit as shown diagrammatically in Fig. 6. E is the charging voltage, R the circuit resistance (variable megohm), L the "Osglim" lamp, C the capacity shunted across the tube electrodes, and *r* a further resistance control (variable 10 000 ohms resistance) in the condenser circuit.

Experiment showed that increase of *r* had the effect of "speeding up" the flashes, but that the area of the cathode employed in the flashing became less; as *r* was increased however, a point was reached at which the discharge became steady and R was evidently the critical resistance value for this arrangement.

Now if C is a small variable capacity (an aluminium vane variable condenser for

* Taylor & Clarkson. *Journ. Sci. Inst.*, V. 1., No. 6, p. 174.

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example), and r is varied, the note in the telephones changes rapidly and it is possible to "run up the scale" by keeping C fixed and increasing r (alternatively by keeping r fixed and varying C). When r attains a certain value the note stops suddenly and a steady discharge ensues.

As a rule for this latter position the discharge is in a *sensitive condition* and small disturbing causes make the discharge variable or intermittent, the intermittency stopping when the cause is removed. Thus, touching the anode terminal with the finger produces a very marked change in the nature of the discharge for the duration of the touch.

As a matter of interest, experiments were made to find out whether the arrangement could be used as a detector of wireless waves. The waves were generated by a small Hertzian Oscillator (that is, an induction coil with capacity and inductance across its sparking points). The following circuit was finally adopted for the reception. It would respond to the waves from the oscillator at a distance of some 20 yards away, by a vigorous flickering of the discharge, the flickering terminating abruptly when the oscillator was not working. Fig. 7 gives the circuit employed. The arrangement is essentially the same as that of Fig. 6, except that an inductance l* is included to give the usual tuned-in circuit, and X is a variable grid-leak connected from the lamp anode to earth, as shown.

As a rule R was made of the order of 0·7 megohms, after which r was adjusted till the sensitive position was attained. If then C and L were adjusted properly, a very noticeable disturbance of the previously steady lamp current was observable, and a flickering, together with a rumbling in the telephones, was produced.

The variable grid-leak to earth from the anode very much increased the efficiency of the arrangement and gave rise to much stronger signals.

The correct interpretation of these interesting effects appears to be as follows. The adjustment of the two circuit resistances brings the lamp to the point corresponding to E on the characteristic (see Fig. 2). If at this point an increase in the voltage across the lamp terminals is produced by the incoming oscillations there will be very little effect on the discharge tube current, but if a small decrease in the potential occurs a very noticeable change in the current through the tube will occur, owing to the steepness of the slope of the characteristic curve in this direction. The action is of a trigger nature, for very small changes produce large effects in the nature of the discharge.

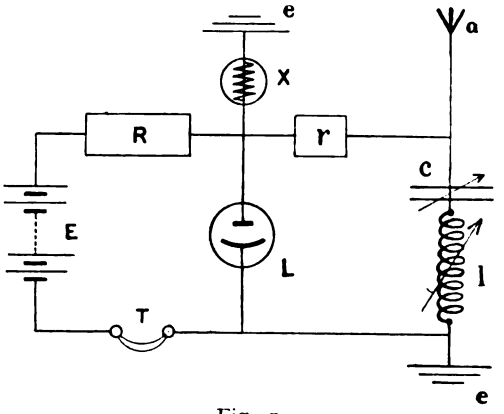

Fig. 7.

Very similar experiments may be carried out at higher potentials with air discharge tubes.

The present writer has not been able, so far, to detect disturbances due to the local broadcasting, etc., in this manner, diversion of the work into other channels having prevented fuller investigation into the matter, but it appears to present a possibly fruitful field for wireless experimenters.

A different method of utilising the neon lamp for the detection of wireless signals has been given by Robinson in Vol. I., No. 1, of EXPERIMENTAL WIRELESS.

* * *

The writer wishes to acknowledge his indebtedness to Mr. A. Bulman, of Armstrong College, to whom the diagrams of the circuits are due.

* The variation of l, the inductance in the circuit produced very little effect, since the form of the wave departs so radically from the simple harmonic form and comprises a very large range of wave-lengths.

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On Crystals and Crystal Testing.

IN our last issue we gave a short note on the methods adopted in our routine tests of valves sent in for report. We must now do the same for crystals.

The basis of judging a crystal is, of course, the characteristic curve showing current against a steady applied voltage in either direction. Such a curve, however, cannot be reproduced very well, as in the case of any decent crystal the "reverse" current is too small to be shown on it. A simple way of getting over this is to draw a curve showing the ratio of the currents in the "pass" and "stop" directions for any applied voltage. In the curves below, the "stop" current is expressed as a percentage of the "pass" current.

There are one or two tricky little points even in drawing the characteristic, if one is to show a fair comparison between different crystals. First, up to what range of voltage shall the curve be taken? Looking at any of the curves below, it is obvious that if the part from 0 to (say) ·3 volts were enlarged to the same size as the whole curve at present, the bend of the characteristic would not appear nearly so sharp, and a false impression might be derived. Similarly, if we compare the curves of two crystals of different resistances, drawn to the same scale, the curve of the high resistance one would be lower on the drawing, and its bend would again appear less sharp, although it might be just as good a rectifier.

This difficulty we get over as follows: the power put into a crystal is proportional to EI, where E is the applied voltage and I the current. So we extend our curves for crystals of various resistances to points representing equal powers, *i.e.*, if a galena of 500O resistance to D.C. at 1 volt has its curve shown up to 1 volt, then a carborundum will be extended until EI=·002, which might occur at say E=2, I=·001, or R=2 000.

In actual practice all ordinary galenas, of resistance 200O to 700O or thereabouts, are shown up to 1 volt.

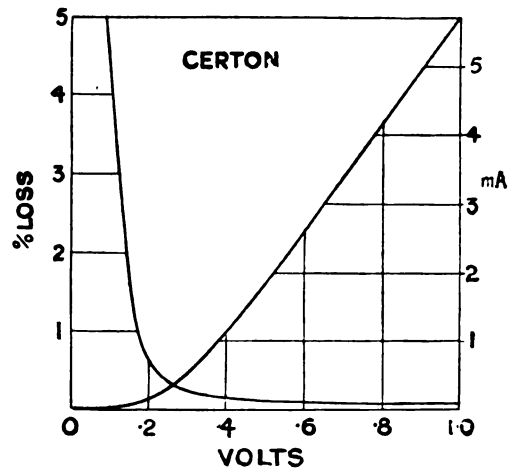
Again, to get over the apparent flatness of curve due to high resistance, all curves are drawn within a rectangle of the same shape, *i.e.*, the current is drawn to a different scale in each case, so that its value at the largest voltage shown, whatever it may be, is represented by the same height on the paper.

Lastly, a note is added as to the type of crystal, and the percentage of points found sensitive on trial. It will, of course, be appreciated that the curves represent the results of one test on one sample. They may or may not be typical of average results.

Two Impandex Crystals.

These were sent in by the Impandex Trading Co., Ltd., 5, Victoria Avenue, Bishopsgate, E.C.2.

One of them, known as Certon, is a normal galena in appearance. Its rectification loss was exceptionally low, being only ·07 per cent. at 1V, and remaining below 5 per cent. at 0·1V. The resistance at 1V will be seen to be 1750. All the points tested were good, and the crystal seemed to enjoy heavy input in a reflex circuit.



The second crystal has suffered an unintentional insult in its name. This is NE●, which we believe is intended by the makers to be a pun on "any spot." Of course the average reader will read it as "No Earthly." The crystal is a very large-grained galena, and as usual in this type there is a tendency for the contact point to slip on the polished surface. But when a steady point is found quite good results are obtained, as will appear from the curves. The crystal shows very low loss for the larger voltages especially. Points tested were 60 per cent. fair, 40 per cent. good. The resistance at 1V was 160O.

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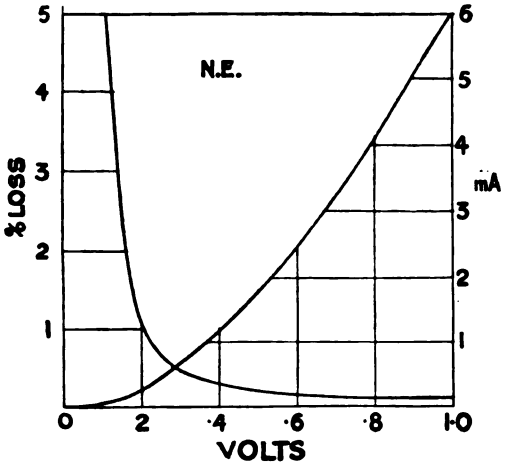
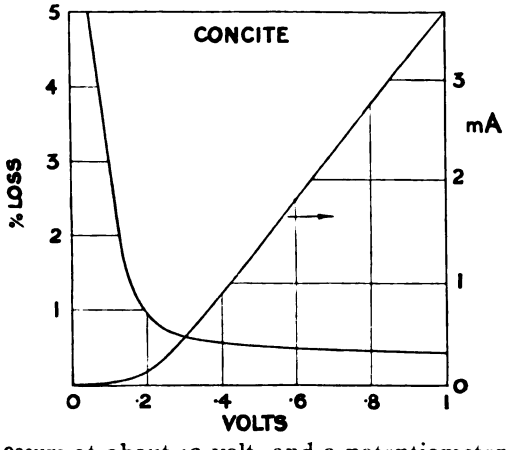


Concite.

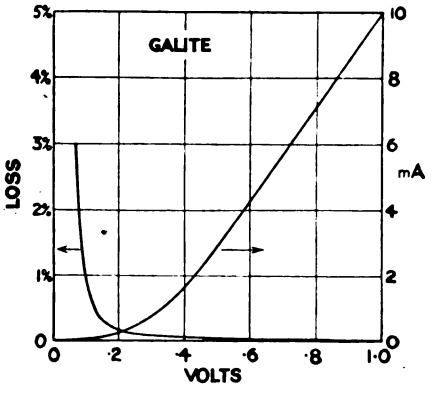
This is a galena of normal appearance, sent for test by Messrs. Conradi & Braun, of 52, Theobalds Road, W.C.1. As shown by the curves herewith, the rectification loss is low—about ½ per cent. for medium voltages. Like most galenas, the bend



occurs at about ·2 volt, and a potentiometer would be an advantage—a point not always appreciated. The curve above the bend is nice and straight, so that there is likely to be proportional rectification for fairly large inputs. The resistance is fairly high, being about 2700 at 1V. Of the points tested 40 per cent. were good, 60 per cent. fair.

Galite.

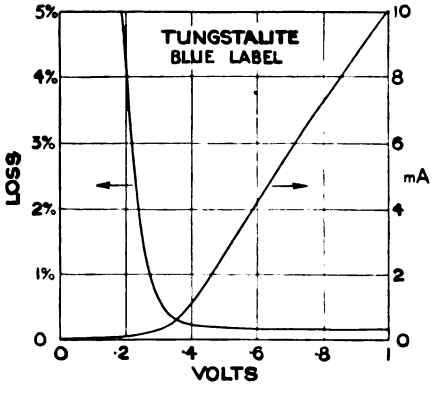
Another typical galena in appearance, submitted by M. A. Gardiner, of 84, Grosvenor Road, N.5. The curves show an exceptionally good rectification, the loss being actually less than ·02 per cent. at high voltages, and only 3 per cent. at the lowest voltage tested. The pass resistance is quite low, being 1000 at 1V. All the points



tested were very good, though not all of them were of the exceptional quality of the curves. On large input, in a reflex circuit, there was a loss of efficiency estimated at 20 per cent.

Tungstalite Blue Label.

This is a synthetic galena made by Messrs. Tungstalite, Ltd., 47, Farringdon Road, E.C.1. It has the great advantage of being unaffected by grease, or the heat of ordinary solder. Its test performance was good, as our curves show, though it is obvious that a potentiometer voltage of about ·3



would give better signals. As usual in synthetic crystals, there are not so many highly sensitive points as in picked natural specimens, the figures being, as regards all points tested, 20 per cent. very good, 20 per cent. good, 40 per cent. fair, 20 per cent. indifferent.

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A Method of Obtaining A.C. for Transmission.

Of particular interest to those possessing D.C. supply. [R355

By J. K. Jennings, B.Sc., and B. L. Stephenson (5IK)

THE problem of obtaining the high voltages required for transmission presents some difficulty, especially where D.C. lighting supply only is accessible. In the authors' case it was very soon found that the 200 volt D.C. supply, while providing an excellent source of H.T. for low power work, was totally inadequate for use with the larger types of transmitting valves. It was therefore decided to try out several methods of obtaining a high voltage from the D.C. mains, and a "Voltage Raiser," similar to that described in No. 5 of EXPERIMENTAL WIRELESS, was first constructed. A four-stage machine was used, each condenser bank being of 18 microfarads, and consisting of waxed paper dielectric condensers of various values built up in parallel. During preliminary tests considerable trouble was experienced with the rotating contacts, which were of laminated copper strip. These were therefore replaced by ordinary carbon motor brushes, which were more satisfactory, in that they did not wear the face of the distributor segments, and consequently less noise was experienced. It was found, however, that the voltage on no external load was much less than the 800 volts which was to be expected, and, in addition to this, the output on load was very rough and irregular. Both faults appeared to be due to leakage in the condensers, so it was decided to make certain alterations to the arrangement of the distributor segments in order to charge the condensers twice per revolution of the charging brushes, and also to eliminate the 90° dead space on the original distributor. Accordingly, a new distributor was built up to the theoretical design shown in Fig. 1.

In this, opposite segments are connected together, thereby allowing each condenser to be charged twice per revolution. Owing to the elimination of the 90° dead space the sizes of the segments had to be very carefully arranged so that no shorting occurred during rotation.

In order to ensure this, each pair of segments had to be of rather different sizes and considerable experimenting was necessary before the final position of the brushes was fixed. As might be expected, the voltage now obtained was higher, and the output much smoother than in the first case. This

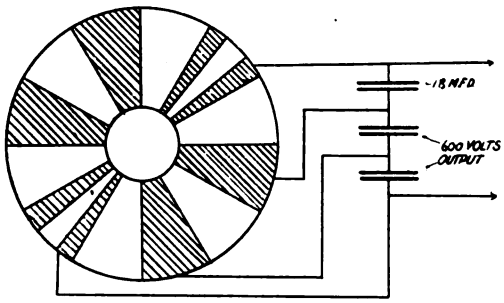

Fig. 1.

arrangement was therefore used for some time at 5IK and gave quite good results. It still had a number of mechanical defects, however, so it was decided to abandon it and try some other method of obtaining H.T. It was considered desirable, if possible, that this should be A.C. in order to give greater flexibility. The arrangement about to be described was ultimately arrived at because of its simplicity and low cost, the fact that the motor which had originally driven the distributor brushes could again be utilised being taken into consideration.

The method employed is one well known in electrical work and consists in converting low voltage D.C. to low voltage A.C. by means of an inverted rotary converter. The A.C. thus obtained is brought to a transformer and stepped up to the required voltage. This can be then rectified either by a chemical rectifier (see No. 3 of EXPERIMENTAL WIRELESS) or by a mechanical rectifier suitably mounted on the shaft of the converter. The output from the rectifier can of course be smoothed if desired before application to the plate of the

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valve. The general arrangement will be seen from Fig. 2. It will be readily understood that this is extremely simple and straightforward and possesses many of the advantages of actual A.C. supply. The power which can be obtained depends entirely upon the size of the converter, and it was found that a large size fan motor was capable of supplying 40 watts rectified and smoothed H.T. to the valve. The cost of running is comparatively low, for in the above case the motor took about 200 watts from the D.C. mains. Most of the loss here is due to the chemical rectifier, which takes considerable current to operate it satisfactorily.

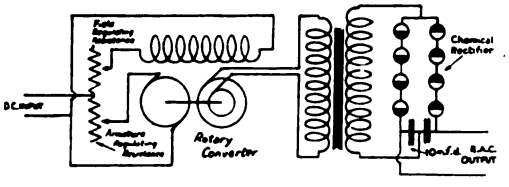

Fig. 2.

It is now proposed to give a detailed description of the plant in use at the authors' station, including the method of conversion of the motor to a converter, and the design and constructional details of the transformer. The power output from the plant is up to 50W at 800V rectified and partially smoothed 50 cycle A.C.

The Rotary Converter.

The rotary converter is an adapted fan motor, the original machine being series wound for 200V D.C. and having a normal input of 50W continuous rating. It was of the totally enclosed type, and as the output required from it would necessitate a considerable overload it was deemed advisable to drill holes in the end plates so as to give increased cooling. It should be understood however that a single phase converter gives 85 per cent. of the output of the same machine run as a D.C. generator, for the same degree of heating. The reconstruction of the machine necessitated the taking of two tappings from opposite segments of the commutator of the motor to sliprings, and the alteration of the field from series to shunt, inserting the necessary resistances which will be discussed later. There was no room inside the machine for these sliprings, and to overcome the difficulty one segment was connected to the shaft, and the tapping from the other was taken out in insulating sleeving through a hole drilled down the centre of the shaft. This lead was connected to a contact stud mounted on an ebonite disc attached to the end of the shaft. The A.C. output brushes were then arranged to run one on this stud and the other on the shaft; Fig. 3 will make this clear.

Operation of the Converter.

Considering the case of a D.C. motor with tappings from opposite segments of the commutator to sliprings, as shown in Fig. 4a, it is clear that in the position of the armature indicated the voltage between the rings will be the same as that of the applied D.C. In Fig. 4b where the armature has rotated through 90°, the armature windings being symmetrical, the voltage difference between the sliprings will be zero.

When the armature has rotated through another 90°, the voltage across the rings will again be equal to that of the D.C. but of opposite polarity. Thus, an alternating E.M.F. is set up between the rings, and this can be considered as being of sinusoidal form. The maximum value of this E.M.F. will be the same as the D.C. voltage, and the R.M.S. voltage will therefore be

$$\frac{\text{D.C. volts}}{\sqrt{2}}$$

It should be borne in mind that with an inverted converter an inductive load, such as transformer load, will cause a weakening of the field and consequent speeding up of the machine, and this will cause increased reactance of load and still further speeding up. By suitable adjustment of the field

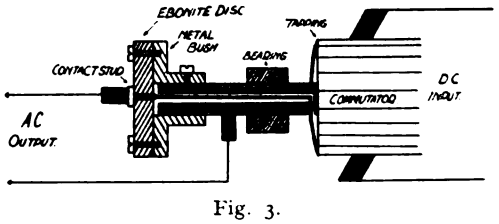

Fig. 3.

current, however, this effect can be minimised so as to cause no trouble. For this reason it is necessary to use a resistance, of value determined by experiment, in series with the field. The frequency of the A.C. produced

$$= \frac{\text{Revs. per minute} \times \text{No. of poles}}{60 \times 2}$$

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so that in a bipolar machine the frequency is the same as the revolutions per second.

The details of the machine used are :—

Resistance of field $=250\Omega$.
Normal load current $=0{\cdot}25$A.
Volts drop in field $=250\times0{\cdot}25=62$V.
Voltage on armature $=200-62=138$V.

It was found that an increase in field voltage to 100 gave greatest stability of the converter, and on 200V supply a series resistance of 250Ω was therefore required. In the case of the armature the voltage could safely be increased to 150V, and as the armature current to the converter on load would be about 1A a resistance of 50Ω was inserted.

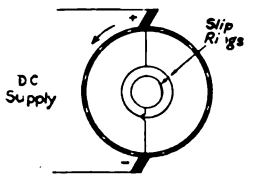

Fig. 4a.

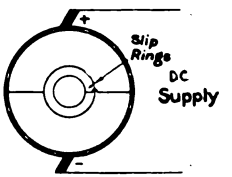

Fig. 4b.

Under these conditions the speed of the machine on no load was 3 000 r.p.m. and the A.C. frequency was therefore 50, the voltage being

$$\frac{150}{\sqrt{2}}=105\text{V A.C.}$$

From these remarks it will be clear that for a different machine or in the case of a different supply voltage, suitable resistances can be selected.

The Transformer.

The transformer is designed round a rectangular laminated iron core, built up from thin iron strip one inch (2·5 cms.) in width. This could be cut into lengths; in the case under consideration two different lengths were required. Three sides only were built up at first, thereby leaving space for the windings to be inserted later. The strips were cut into lengths L and L_2 and assembled as shown in Fig. 5.

The first layer is shown by dotted lines and the second layer by thick lines. The third is then similar to the first and so on. This forms a complete magnetic circuit. When laminations have been built up to the required thickness they are held together by clamping one side (AB) between two strips of iron of about the same width as the laminations. It will be found that ribbed iron, such as that used for angle brackets, is very convenient for this purpose. The method of holding these strips together is shown in Fig. 6.

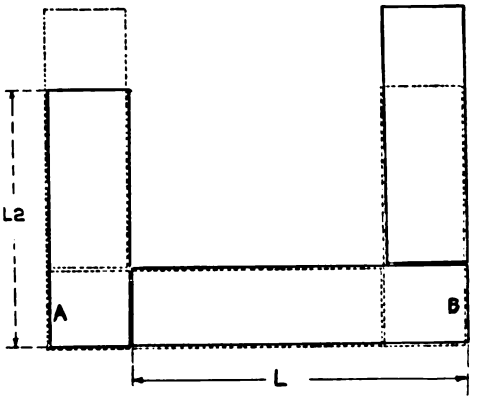

Fig. 5.

The primary and secondary coils are wound separately on formers made from sheet presspahn, and are slipped over opposite arms of the core. The open end is closed up by further strips (employing the same method of jointing as before) and is then held by a second clamp.

Design of Transformer.

Requirements: Output $=80$ watts (sufficient to cover rectification losses, etc.).
Secondary voltage $=800$.

Supply available from converter: 105 volts, 50 cycles (no load).

Owing to the comparatively high resistance of the armature winding, the voltage on load will drop considerably and we will therefore assume the voltage to the primary

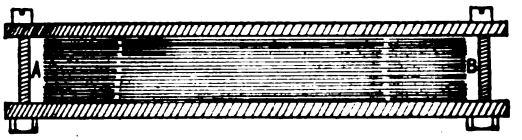

Fig. 6.

to be 90V. Further, assuming that the efficiency of the transformer is 80 per cent. the input required will be

$$\frac{80\times10}{8}=100\text{W},$$

and the approximate current will be

$$\frac{100}{90}=1{\cdot}1\text{A}.$$

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It is convenient to take the depth of winding to be 1 cm., and it is found that a current density of 550A per sq. cm. will not cause any overheating. The sectional area of the wire is then $\frac{1 \cdot 1}{550}$ sq. cm. and this equals $\frac{\pi d^2}{4}$ where d is the diameter.

Therefore

$$d = \sqrt{\frac{1 \cdot 1 \times 4}{500 \times \pi}} = 0 \cdot 05 \text{ cm.},$$

and this is 24 S.W.G. approximately. This size of wire is not unreasonable, and will be adopted for the present.

The number of turns required and the necessary flux are found from the following :—

The voltage produced in a coil of N turns by an alternating flux of maximum value Q_m at F cycles is given by :—

$$E = 4 \cdot 44 \, FNQ_m \times 10^{-8}$$

In our case therefore

$$90 = 4 \cdot 44 \times 50 \times NQ_m \times 10^{-8}$$

$$i.e., \quad NQ_m = \frac{90 \times 10^8}{4 \cdot 44 \times 50} = \cdot 4 \times 10^8$$

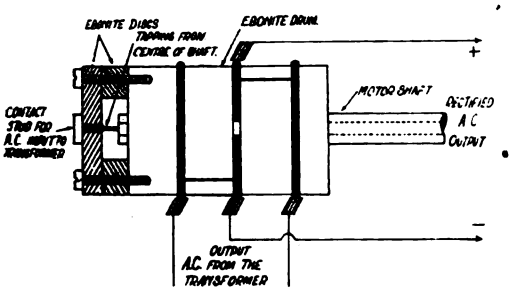

Fig. 8.

From this it will be seen that it is possible to have either a large number of turns and a small flux or vice versa. The amount of iron needed, however, depends on the flux to be carried, and for greatest efficiency it is desirable to have the iron and copper losses approximately equal.

For a trial we will assume the number of turns to be 1 000 and take the depth of winding as being 1 cm. Then, if we wind the coil layer for layer and allow ·03 cm. for the D.C.C. insulation, we have :—

$$1000 = \frac{1}{\cdot 086} \times \frac{L}{\cdot 086}$$

where L = the length of the coil.

In this L = 7·4 cm. which, for constructional reasons, is rather large. We shall therefore increase the depth of winding to 1·6 cm. so that the length of coil will now be 4·5 cm. Now the flux

$$Q_m = \frac{\cdot 4 \times 10^8}{1000}$$

and taking a flux density B = 9 000 lines per sq. cm. we have the area of iron needed

$$= \frac{Q_m}{B} = \frac{\cdot 4 \times 10^8}{1000 \times 9000} = 4 \cdot 4 \text{ sq. cm.}$$

As the standard width of the iron stampings is 2·5 cm. we have :—

The thickness of stampings to be built up

$$= \frac{4 \cdot 4}{2 \cdot 5 \times \cdot 9} = 2 \text{ cm.}$$

(An allowance of 10 per cent. is made in the above equation for paper, varnish, etc., on the stampings.)

Secondary Winding.

Voltage required = 800.

Primary voltage = 90.

The number of turns on the secondary will therefore be $\frac{800}{90} \times 1000 = 9000$ approximate.

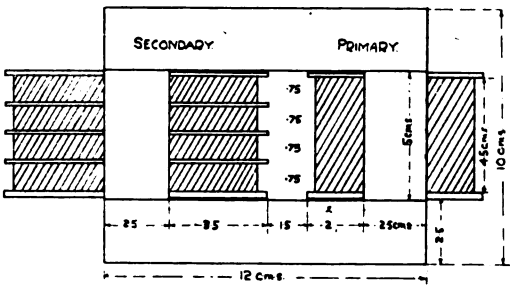

Fig. 7.

The secondary current is ·1A and the current density can be taken as 400A per sq. cm.

The area of the wire is $\frac{\cdot 1}{400}$

and the diameter is therefore

$$\sqrt{\frac{\cdot 1 \times 4}{400 \times \pi}} = \cdot 015 \text{ cm.}$$

This is 38 S.W.G., but for mechanical reasons it is advisable to use 36 S.W.G. D.S.C. (·029 cm. diameter over D.S.C. insulation).

Owing to the high voltage it is necessary to divide up the winding into four sections and the details of the bobbin are given in Fig. 7. It will be seen that the total width

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of winding is 3 cm., so that the depth will be

$$\frac{9\,000 \times \cdot 029 \times \cdot 029}{3} = 2\cdot 5 \text{ cm.}$$

but owing to the narrowness of the sections (·75 cm.) we shall allow a depth of 3 cm.

Complete Data for Windings.

	Primary.	Secondary.
Size of wire	24 S.W.G., D.C.C.	36 S.W.G., D.S.C.
Number of turns ..	1 000	9 000
Length of wire required	550 feet	6 250 feet
Size of former ..	2·5 × 2 cm. (to fit over iron section)	2·5 × 2 cm. (to fit over iron section)
Outside dimensions of winding	5·7 × 5·2 cm.	8·5 × 8 cm.
Width of bobbin ..	4·5 cm.	4·5 cm. (divided up into four sections each approximately ·75 cm. in width).

Fig. 7 shows the main dimensions of the transformer.

To check the previous figures it will be advisable to estimate the various losses in the transformer.

Iron loss at 9 000B at 50 cycles = ·04W per cu. cm.

Volume of iron = 180 cu. cm.

Therefore total iron loss = 180 × ·04 = 7W.

Primary resistance = 9O.

Therefore primary copper loss = $9 \times 1\cdot 1^2 = 11$W.

Secondary resistance = 1 000O.

Therefore secondary copper loss =

$$1\,000 \times (\cdot 1)^2 = 10\text{W}.$$

This gives a total loss of approximately 28 watts and the efficiency is therefore 100—28 = 72 per cent. This is quite good considering the small size of the transformer and the fact that it is a very economical one to make. The copper losses are rather high compared with the iron losses but iron is less expensive than copper.

We can therefore consider our preliminary assumptions to be reasonably correct.

Mechanical Rectifier.

Such a rectifier must of course be synchronous, and by far the most convenient method is to arrange the necessary apparatus on the shaft of the converter. This can be done by mounting an ebonite drum of, say, 4 cm. diameter on the end of the shaft. This drum has three grooves about 2 cm. apart cut round its circumference and rings of thick copper wire are fixed in the outer ones. This can be done by heating the rings and then slipping them over the ebonite and allowing them to contract into the grooves.

The ring to be placed in the centre groove is split in halves and shortened so as to give gaps between each half of about 1·5 cm. The arcs are then held in position by flattening their ends and putting through small countersunk screws into the ebonite, and each one is connected to an outer ring. One carbon brush is arranged to run on each outer ring and two (at 180°) on the split ring. The operation and general features will be understood from Fig. 8. The drum can be a tight fit on the shaft or it may be held in position by a flanged bush. Its correct position is such that the peak of the A.C. wave occurs at the centre of the arcs comprising the split ring. This condition is fulfilled when the centres of the arcs are opposite the tapped commutator bars. The two brushes on the split ring, in order to take off the peak, must be in the same plane as the D.C. brushes on the converter, or possibly lagging these a few degrees.

In the case of the chemical rectifier it was found that the arrangement shown in Fig. 2 gave the most satisfactory results. Each bank consists of eight cells, the current density allowed being 6 milliamps output per sq. cm. of plate. The condensers are 10 microfarads each, thus giving considerable smoothing.

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Amateur Transmission.

THE most important work done by amateur transmitters on the scientific side, as distinct from the technical, has been connected with the investigation of the varying properties of different wave-lengths. In this connection the statistics collected by the American Bureau of Standards from broadcast listeners are of interest, indicating that a minimum of reception strength occurs at a distance proportional to the wave-length; about one-quarter of a mile per metre. This is borne out fully in Edinburgh, where the Aberdeen and Newcastle stations, both about a hundred miles distant, are received very poorly, while stations further south are received much louder. This result appears to be obtained in other parts of the country. One explanation given is that besides the main ether wave, a wave travels at a different speed through the outer layer of the earth, and owing to the difference in velocity causes an interference band.

On examining results obtained with the transmitter 5JX it is found that they agree with the above observations. On 120 metres a minimum should be observed at about 30 miles, and it is a fact that at times when loud signals are reported at a distance of 1000 miles, Glasgow, 40 miles distant, and Dollar, 30 miles, report poor signals. It would be interesting to know if this experience is general, and particularly as regards waves of 50 metres or less now being used by several experimenters. In the latter case it would even be practicable to mount a portable receiver on a car and make observations of strength at varying distances, care being taken to avoid such effects as local screening, etc., as much as possible.

Experiments at 5JX indicate that fading is not entirely absent on waves below 150 metres, as is sometimes stated, but that it is usually slight or altogether absent, and, exceptionally, may be very bad. Signal strength curves showing fading of 5JX have been obtained simultaneously from a number of districts, and these show that even in districts separated by a few miles, the fading varies in quite a different manner; at the same moment signals may be steady at one point of observation, and fading very pronounced at another only 10 miles away, and when fading takes place at both, the curves do not in the slightest degree correspond. It is rather surprising that this should be so, as it would be expected, according to the present theory of fading, that the phenomenon would affect a particular district in an appreciably similar manner at nearby points.

Detailed reports of signals from 5JX, whether special tests or not, are always welcomed as supplying information on these matters relating to the propagation of short wave signals. Signals are frequently sent after B.B.C. hours on about 120 metres.

Some Interesting Transformers.

The Monopole.

THE Monopole L.F. transformer, handled in this country by Mr. P. Capel, 3 and 4, Queen Street Arcade, Cardiff, is a typical example of French audacity. We are accustomed in this country to attribute much evil to the close juxtaposition of two L.F. transformers; what then shall we say to the idea of enclosing two, or even three, in the same case, with their cores parallel? Yet this is done quite successfully in this case. The secret is the use of a core with no magnetic joint at all—a closed ring—with windings, one over the other, covering the whole of it, so that leakage is *really* negligible. The sample tested was of the double type, the first 5 to 10, the second 3 to 1. We tried each part of it separately and also the two together, the method being the simple one of switching over on broadcasting, with a specially accurate type of audibility meter in use, while at the same time two independent judges compared tone.

The standards of comparison were first-class commercial transformers, each one used in the stage which it suits best. The results, as regards strength, were:—

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Position	After Crystal	After Ordinary Valve	After Power Valve
Approx. Impedance ..	4 000O	25 000O	6 000O
Ratio of standard .. Transformer	4/1	4/1	3/1
5 to 1	1·2	1	1·6
3 to 1	1·1	1	1·4

The figure giving in each case comparative strength, and accuracy of test being about 5 per cent.

As regards tone, both the units gave admirable results after the crystal; but in the later stages they gave a rather high tone, a small condenser across the secondary (about ·0007) giving improved richness.

On wiring both transformers simultaneously for the first and second stages, their performance was exactly the same as when used separately: there appeared to be no interaction.

The price is low, being 24s. for the double type, which replaces two ordinary transformers.

The Marconi Ideal.

The Marconiphone Co. recently sent us some literature dealing with their new L.F. transformers, from which we gathered that they had attempted to make a practically perfect transformer by sparing no effort either in design or manufacture. The data given seemed interesting, so we have tested samples of these transformers with especial care.

We may state at once, before going into detail, that the results were exceptionally good.

The construction of the transformer is, as will be seen from our sketch, unusual. The secondary is in four sections of which the end ones apparently contain more wire than the middle ones: the primary is in three equal sections. Each section is spaced about $\frac{1}{16}$ in. from its neighbours. The core is extremely large, having a cross section of $1 \times \frac{3}{4}$ in. The number of turns is not stated, but the ratio is 2·7, 4 or 6 to 1 in the three models, which are otherwise identical. The transformer is enclosed in a light sheet-iron case.

The performance claimed by the makers is an extraordinary one. They offer the two lower ratios as suitable for valves of high or medium impedance, and the 6 to 1 for low impedance (power) valves: they do not claim perfection of quality with the 6 to 1 ratio on high impedance valves.

Curves of performance (stage step-up against frequency) are given on the guarantee card which accompanies the valves. The worst of these shows a drop of 20 per cent. (just perceptible) at 300 and 4 000 cycles, as compared with the step-up at about 1 000. Most of them show a drop of about 7 per cent. between 750 and 300 cycles, and even amplification above. These curves are apparently the Company's own tests, but the guarantee given is that every transformer will be within 5 per cent. of the curve, and it also provides for replacement in case of breakdown within 6 months.

We have dealt with these matters at greater length than our custom; we are led to do so by the fact that this is, as far as we know, the first attempt by a manufacturer to offer a close performance specification on such a tricky thing as a transformer.

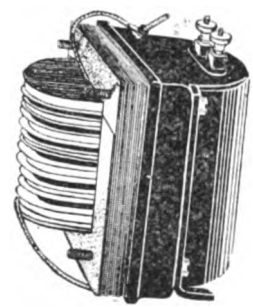
Now for results: we have already described our method, and the strength test resulted as follows:—

Position	After Crystal	After Ordinary Valve	After Power Valve
Approx. Impedance ..	4 000O	25 000O	6 000O
Ratio of standard .. Transformer	4/1	4/1	3/1
6 to 1	2	2·7	1·4
4 to 1	1·4	2	1·4
2·7 to 1	1	1·4	1·25

The quality is, we believe, better than any we have previously heard. Our standards give us a tone which sounds absolutely satisfactory; but on a very careful test we find that the Marconiphone curves are justified: there is a distinct increase of comparative strength of the extreme top and bottom notes with the Marconi when the main bulk of the music is of equal loudness in both transformers.

One result of the extremely low self-capacity must be noted: the transformer is extremely sensitive to added capacity; even a condenser of ·0005μF across the secondary causes a great change of tone in the higher ratios.

Further, the self-capacity is so low that it will not by-pass H.F. currents as it will in most transformers. Hence the transformer is difficult to use in reflex circuits. We found it impossible with our usual series H.F. and L.F. connections, and had to change over to the parallel arrangement, with stop condenser and radio-frequency choke.



The transformer is expensive—it costs 35s.—but we believe it to be of such exceptional quality as to be good value. A disadvantage inherent in its quality is the large size; it is $3\frac{3}{4}$ in. by 3 in., and $3\frac{1}{4}$ in. high overall.

Editorial Note.

We have received many inquiries from readers regarding an index and also binding covers for the first volume of EXPERIMENTAL WIRELESS & THE WIRELESS ENGINEER. *We have pleasure in reporting that these are now in course of preparation. The index will probably be included in our next issue, when particulars will be given of the binding covers.*

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Letters of interest to experimenters are always welcome. In publishing such communications the Editors do not necessarily endorse any technical or general statements which they may contain.

Direct Current Measuring Instruments.

The Editor, E.W. & W.E.

SIR,—With reference to the article by Mr. Leonard A. Sayce in the September issue of E.W. & W.E., I have had two Weston relays in use, one as a voltmeter and one as an ammeter, for some time, and they have given every satisfaction. Personally, I prefer to use the instruments in a horizontal position, and for this they are fitted with the usual three legs, two of which are fine-threaded screws. A circular spirit level, such as are used on cameras, is fixed to the top of the instrument. The hair springs by which the current is led to the moving contact were not removed, and whilst not quite so sensitive as the one described, the instruments gave a full scale deflection with 0·00 4 ampère, equivalent to 0·00001 ampère per division. A shunt box is used in conjunction with the ammeter, and a series resistance box with the voltmeter. The ammeter ranges are: 0·0004, 0·001, 0·002, 0·004, 0·01, 0·02, 0·04, 0·1, 0·2, 0·4, 1, 2, 4 and 10 ampères. The voltmeter ranges are: 0·15, 0·3, 0·6, 1·5, 3, 6, 15, 30, 60, 150 and 300 volts. For accurate work a number of ranges are necessary owing to the shortness of the scale.

H. H. DYER.

22, Leopold Street,
Derby.

The Editor, E.W. & W.E.

SIR,—The following notes may usefully supplement my article on the conversion of Weston relays, which appeared in the September issue of EXPERIMENTAL WIRELESS & THE WIRELESS ENGINEER:—

The range of the converted relay may be extended to any desired extent by the provision of suitable shunts.

If the total current $= I$
the portion flowing through the instrument $= I_g$,
the portion flowing through the shunt $= I_s$,
Resistance of instrument $= R_g$,
Resistance of shunt $= R_s$,
then

$$R_s = \frac{I_g \times R_g}{I - I_g}$$

The instrument itself gives a full-scale deflection for (say) 0·000 28 amp. Suppose we wish to use it as a milliammeter, for plotting valve characteristics. It would be convenient if it registered 0 to 8mA. Taking the resistance of the coil (R_g) at 350ω:—

$$R_s = \frac{I_g + R_g}{I - I_g} = \frac{\cdot 00028 \times 350}{\cdot 008 - \cdot 00028} = 12\cdot 7\omega$$

A resistance coil of this value can be made by taking 12 in. of No. 40 D.S.C. Eureka resistance wire and winding it upon a short length of ebonite rod.

Thus the converted relay can provide us with a means of measuring small or large currents of any order of magnitude. But its utility need not stop here, for it may serve as a voltmeter of any range if suitable resistances are included in series with it. Suppose, for instance, that we require to make it into a voltmeter having a range of 0 to 8 volts. We have assumed that a current of .000-28A produces a full-scale deflection, so the total resistance of moving coil and series resistance must be such as to pass this current when the voltage across them both is 8. The total resistance must then be $8 \div 000\ 28 = 30\ 000\omega$, *i.e.*, the added series resistance must be in the order of $29\ 700\omega$.

In conclusion, it may be pointed out that the movement of the Weston relay is of the finest construction, so that, if care is taken, there is no reason why the converted instruments should not give every satisfaction.

LEONARD A. SAYCE.

Sunderland.

High Frequency Resistance.

The Editor, E.W. & W.E.

SIR,—Your footnote to my article on "An Experimental Determination of High Frequency Resistance" in the September issue of E.W. & W.E. anticipates a somewhat similar table of results by other experimenters which it was my intention to send you. Consideration of these figures has led me to believe that the disparity between my results and those of the formulæ is probably due to the error introduced by the ammeter, for the hot wire in this instrument is divided into four parallel paths, and the slightest lack of symmetry in the inductance of these paths

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will produce a non-uniform distribution of current in the wire. This will cause a larger deflection for a given current than would otherwise be the case.

I should also like to thank Mr. Edward Hughes, B.Sc., A.M.I.E.E., of Brighton Technical College, for his helpful advice at all stages of the work and for permission to use the apparatus required.

W. G. WHITE.

Brighton.

A Full Wave Rectifier.

The Editor, E.W. & W.E.

SIR,—Since writing the article on the above, I have adjusted several buzzers for friends who have made up similar rectifiers, and in all but one case the buzzers operated quite satisfactorily without any magnetising current. In the odd case, the magnet was not sufficiently magnetised, but using the 32 ohm windings in parallel made the magnet too strong. It appears from this that the strength of the magnet in relation to the flux due to the operating current is important. I mention this in case difficulty is experienced in obtaining sparkless rectification. I myself have had a buzzer running quite satisfactorily with a permanent magnet for about two months.

May I call attention to a little slip in the size of the base? The thickness is given as 3½ in., this should be ¼ in. In column four of the table P.N. should be P.M., meaning, of course, permanent magnet instrument.

H. H. DYER.

22, Leopold Street,
Derby.

A Universal Meter.

The Editor, E.W. & W.E.

SIR,—In reply to Mr. E. Lester Smith's criticism of my article "A Universal Meter," I was, of course, aware that the field should be radial and also that in *pivoted* commercial instruments this condition is obtained by using circular pole pieces and a fixed iron centre. This construction does not, however, increase the sensitivity unless it is carefully constructed so that the two air gaps in series are less than the air gap in the type described. Since this type of coil has four faces to keep clear of the stationary parts instead of two, the instrument as made by the amateur would probably have a much larger total air gap than the type described. The standard of workmanship in commercial moving coil instruments is very high indeed. Most *suspended* coil commercial instruments have no iron centre and flat pale faces.

It is certainly not desirable to use a very long scale, but if this error is avoided very satisfactory results can be obtained.

I enclose a comparison of the readings on the instrument illustrated in my article and of a Weston ammeter placed in series with it. It will be seen that the combined effect of all the errors of design and construction are by no means as serious as Mr. Smith seems to fear.

I agree, however, that it would be preferable to take more than one point. The suggestion to make the curve from one point was intended for experimenters who had only one standard 1 000 ohm resistance as mentioned. I expected that those who had better facilities for calibration would use them.

Home-Made Instrument.		Weston Instrument.
Even Scale Division.	Reading + 1·100	
11	·010	·010
22	·020	·020
32	·029	·030
44	·040	·040
57	·052	·050
69	·063	·060
82	·074	·070

Leicester. HAROLD E. DYSON.

Spark Jamming.

The Editor, E.W. & W.E.

SIR,—Regarding Mr. R. H. P. Collings' letter in the current issue, this end of the Channel is certainly a hotbed of spark jamming. I think the chief trouble with FFU is that it radiates harmonics to a greater extent than most spark stations. Here (just by Plymouth) FFU is not nearly so bad as it is farther west. The French trawlers, however, often seriously interfere with 5PY at a distance of only half a mile from the latter. Naval buzzer sets and Rame Head are sometimes bad, and an occasional foreign liner or American cargo boat yelling for FFH, or even PCH, liven matters up. Even heart-shaped reception does not avail at times, and, of course, any form of tuning, including rejecting, is useless. The employment of a limiting valve, however, in conjunction with judicious use of loose coupling, *will* do the trick.

L. J. VOSS.

Saltram Point,
Plympton,
Devon.

H.F. Amplification.

The Editor, E.W. & W.E.

SIR,—I note with interest an article in the September issue of EXPERIMENTAL WIRELESS by Mr. Lewer on the use of Low-Frequency Amplification for Long Distance Reception. I am, however, amazed at the last paragraphs, in which the author compares H.F. and L.F. for DX work. There has recently been a wave of feeling against H.F. amplification, but I am very disappointed that anyone who has done such wonderful reception as Mr. Lewer should adopt this attitude.

Some time ago H.F. was in invariable use, but now, as we drop to shorter waves, H.F. is being dropped also. When we worked on 1 000 metres we said H.F. was only just possible and not much good below that figure, we found later that this was not so. It is the same in this instance. H.F. will work as low as one cares to make it.

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Consider Mr. Lewer's table. (1) Selectivity. H.F. has the advantage of cutting out local interference to a great extent and is undoubtedly a help. However, Mr. Lewer says this tends to become a disadvantage when receiving weak signals. Since we are discussing receiving C.W. in an oscillating state, I should like to know how the selectivity effects it—obviously it cannot. What happens is that the tuning is sharper and stations are liable to be passed over. The cure is obvious —use a much smaller tuning condenser, with a fine adjustment.

On 100 metres about ·0001 is the minimum desirable capacity for normal work and this is best provided by a small fixed condenser in parallel with the usual one. This flattens the tuning merely because the range with the coil is not as great, but it does not increase the selectivity. The sensitivity advantage is of course very great. The extra difficulty in tuning is not noticeable if the set is properly designed. The reaction coil needs only infrequent adjustment if correctly made and it is just a matter of practice.

The second disadvantage does not exist. To all intents and purposes everyone reacts from the detector to the aerial nowadays and the aerial resistance loss is got over as with the other method. The extra capacity in detector grid circuit mentioned is a point I fail to see, for if the set is designed there is less capacity on an H.F. set detector than on an L.F. set. The body capacity effects are easily avoidable and a set using L.F. is just as susceptible if badly designed.

Not only is H.F. a great benefit on 50 metres but it is also possible to obtain noticeable amplification of about 20 per cent., using four-pin valves, on waves between 20 and 30 metres. Using V-24 valves and a set built for the job, instead of putting in condensers and coils of slightly smaller sizes, I am positive H.F. can be made enormously worth while down to 20 metres or below.

FREDERIC L. HOGG.

Running Valves in Parallel.

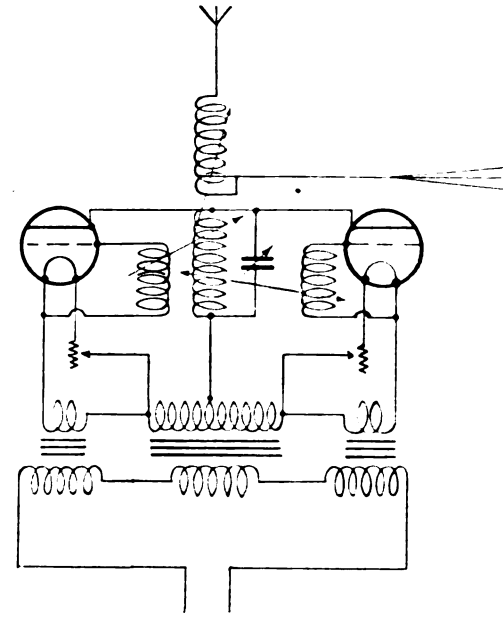
The Editor, E.W. & W.E.

SIR,—In looking over the August number of your magazine, I noticed an article on radio station G5RZ. I also note that difficulty was found in balancing two valves when used on opposite sides of the circuit.

The writer had the same difficulty several years ago, and resolved to correct it by changing the circuit, but at the same time to rectify both halves of the wave. This was done by connecting the two plates together and running this common terminal through the helix and back to the centre tap on the transformer. The separate filament transformers which were well insulated were attached to the ends of the high tension supply. The grids were coupled inductively to the plate coil, and by placing a milliammeter in each plate circuit the two tubes could be balanced perfectly by varying the position of each grid coil separately. The diagram herewith explains this.

The writer found after a number of experiments on this that a similar scheme had been worked out in the Navy in some experimental work along the same lines.

While this scheme necessitates well insulated filament transformers, it is frequently of value where the difficulties of balancing tubes in the ordinary circuit become great.



In connection with your electrolytic rectifiers, I am wondering if you are familiar with the tantalum rectifier, employing tantalum and lead electrodes in a 10 per cent. or 15 per cent. solution of sulphuric acid. The rectifying action is much better than aluminium. A commercial form of six-volt battery charger, employing this rectifier unit, is quite popular here, and I understand that the Fansteel Company of North Chicago, Illinois, who manufacture the tantalum, are selling electrodes for high tension rectifiers for which they claim rather remarkable results. I am rather sure that a word to them from you would bring some very interesting information.

JOHN H. MILLER,
Electrical Engineer,
Jewell Electrical Instrument Co.
Chicago.

[The difficulty with regard to the tantalum rectifier, in England, has been to obtain plates: we are taking up Mr. Miller's hint, and will report results in a later issue.—ED., E.W. & W.E.]

A CORRECTION.—In the article entitled "Further Notes on Resistance-Capacity Amplification," by F. M. Colebrook, published in last month's issue, an error occurred on p. 716. The first equation was printed as $Z = R \cdot \frac{1}{\omega C}$. The $\times$ sign should of course have been $\div$.

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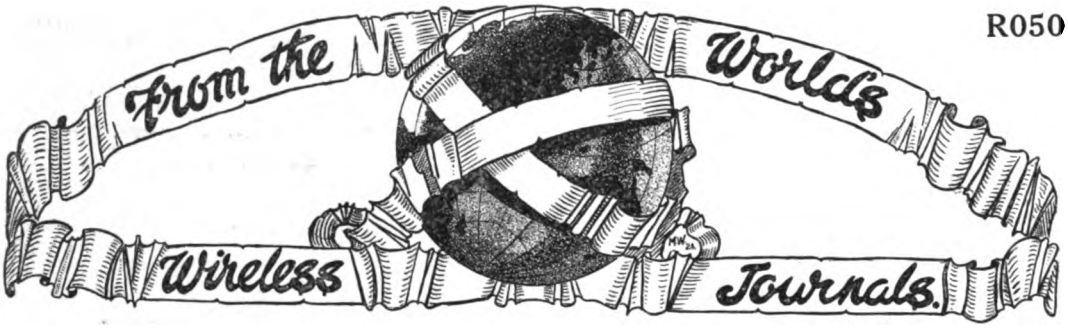
R050



R100.—THEORY AND PRINCIPLE.

R110.—A New Theory of Long Distance Radio Communication.—Prof. G. W. O. Howe, D.Sc. (*Electn., Sept.* 12, 1924).

An analysis of the propagation of wireless waves, based on an assumption of the Heaviside layer.

The Dielectric Properties Required for Maxwelian Radiation.—A. Press. (*Phil. Mag.*, Sept.).

A mathematical analysis.

R121-2.—Nodal Points and Aerial Tuning.—P. K. Turner (*Exp. W.*, Sept.).

A simple theoretical discussion of the potential distribution along an aerial with respect to frequency and aerial length. An analysis is given showing how the harmonics of an aerial may be deduced for given aerial constants and loading values.

R148·1.—Faithful Reproduction in Radio-Telephony.—L. C. Pocock, B.Sc. (*Journ. Inst., E.E.*, Sept.).

A general consideration of the transmission of articulate speech by wireless. Various types of distortion are analysed, namely, frequency distortion, amplitude distortion, faulty modulation, additive distortion and the non-linearity of the response characteristic of the human ear.

R200.—MEASUREMENTS AND STANDARDISATION.

R210.—Wavemeters for the New Ranges.—S. Kruse (*Q.S.T.*, Sept.).

Description of method of calibrating a wavemeter for wave-lengths between 20 and 80 metres by using the harmonics of another wavemeter built for the 200 metre band.

R240.—An Experimental Determination of High Frequency Resistance.—W. G. White (*Exp. W.*, Sept.).

Some measurements of H.F. currents at various frequencies by the use of a thermo-junction to measure the heating effect of the currents on a test wire.

R250.—Hot Wire *v.* Thermocouple Ammeters.—H. B. Richmond (*Q.S.T.*, Sept.).

A summary of the relative merits of the two types of H.F. ammeter.

R270.—Transmission Experiments at 8AQO.—S. Kruse (*Q.S.T.*, Sept.).

First part of an article describing some experiments to test the relative merits of the buried earth and counterpoise for transmission on various wavelengths.

R300.—APPARATUS AND EQUIPMENT.

R342·2.—Further Notes on Resistance-Capacity Amplification.—F. M. Colebrook (*Exp. W.*, Sept.).

A detailed article on resistance amplifiers for speech frequencies. Careful attention is given to conditions of working, particularly to the best values of anode resistance, grid-leak and coupling condenser.

R342·5.—Construction d'Amplificateurs de Puissance.—P. Dastouet (*R. Elec.*, Aug. 25).

A short description of a two-stage transformer-coupled power amplifier and a resistance-coupled push-pull power amplifier for loud-speaker work. Constructional details of intervalve power transformers are given.

R342·7.—The Use of Low-Frequency Amplification for Long-distance Reception.—S. K. Lewer (*Exp. W.*, Sept., 1924).

Some practical notes on the reception of signals using a detector valve with reaction followed by low-frequency ampification.

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R342·701.—THE PERFORMANCE AND PROPERTIES OF TELEPHONIC FREQUENCY INTERVALVE TRANSFORMERS.—D. W. Dye, B.Sc. (*Exp. W.*, Sept.).

Methods are described for measuring the effective primary inductance and resistance of audio-frequency intervalve transformers.

R343.—A COMBINED TEST AND BROADCAST RECEIVER.—(*Exp. W.*, Sept.).

Details of an ingeniously designed receiver for testing all kinds of circuits and components.

R343·5.—GETTING RESULTS WITH AN ARMSTRONG SUPER. J. G. W. Thompson (*W. World*, Aug. 27 and Sept. 3).

Description of a compact super-regenerative set for short wave reception. The electrical constants of various components are given, together with some details of the performance of the set.

R370.—THE BEST CRYSTAL CIRCUITS.—W. B. Medlam, B. Sc. and U. A. Oschwald, B.A., (*W. World*, Aug. 20 and Aug. 27).

A discussion on the relative merits of different crystal circuits for reception on broadcast wave-lengths. Results are given of quantitative observations with various values of inductance in the aerial and crystal circuits.

R376·3.—THE EFFECT OF A HORN ON THE PITCH OF A LOUD-SPEAKING TELEPHONE.—E. W. Kellogg (*Gen. El. Rev.*, Aug.).

An interpretation of certain formulæ developed by Lord Rayleigh.

R382·6.—THE BASKET-WEAVE COIL.—G. W. Pickard (*Q.S.T.*, Sept.).

Note on losses and wire sizes in the Lorenz-type winding.

R386.—FREQUENCY FILTERS.—E. K. Sandeman, B.Sc. (*W. World*, Sept. 3 and Sept. 10).

An elementary consideration of electrical and analogous mechanical filters for the purpose of allowing the transference of energy at certain frequencies and the suppression of other frequencies. High-pass, low-pass and band-bass filters are described.

R400.—SYSTEMS OF WORKING.

R402.—WORKING AT 20, 40 AND 80 METRES.—S. Kruse (*Q.S.T.*, Sept.).

Some notes on reception and transmission on these short wave-lengths. Several suitable receiving circuits, as well as transmitting circuits, are given, with data of size of capacities and inductances required.

R500.—APPLICATIONS AND USES.

AIR MAIL WIRELESS EQUIPMENT. — *W. World*, Sept. 10).

A description of the transmitting and receiving equipment used on the aeroplanes of the U.S. Post Office Department.

R600.—STATIONS: DESIGN, OPERATION AND MANAGEMENT.

R610.—5XX.—(*Exp. W.*, Sept.).

A technical description of the British Broadcasting Company's high-power station.

R800.—NON-RADIO SUBJECTS.

PROPERTIES OF FUSIBLE ALLOYS. (*W. World*, Aug. 20).

A short note on the composition and properties of various well-known fusible alloys.

DESIGNING SMALL POWER TRANSFORMERS.—W. James (*W. World*, Aug. 27).

An elementary résumé of the principles involved in the design and construction of transformers for small powers at commercial frequencies.

SOUND IN RELATION TO WIRELESS.—Prof. E. Mallet, M.Sc. (*W. World*, Sept. 10).

A general explanation of the nature of sound and wave-motion in material media.

A SIMPLE METHOD OF MAKING DIRECT-CURRENT MEASURING INSTRUMENTS.—L. A. Sayce, M.Sc. (*Exp. W.*, Sept.).

A description of how ex-W.D. Weston relays may be converted into D.C. measuring instruments.

A FULL WAVE RECTIFIER.—H. H. Dyer (*Exp. W.*, Sept.).

Description of how a vibrating rectifier can be constructed from an ex-W.D. D III. buzzer.

THE PROBLEM OF HIGH-TENSION SUPPLY, IV.—R. Mines, B.Sc. (*Exp. W.*, Sept.).

One of a series of articles on high-voltage supply for power valves, etc. Induction coil and interrupter methods are described for driving high-tension A.C. from low-tension D.C. sources.

STUDIES OF ELECTRIC DISCHARGES IN GASES AT LOW PRESSURES.—Dr. Irving Langmuir and H. Mott-Smith (*Gen. El. Rev.*, Aug.).

Experimental data, illustrating the use of plane collectors.

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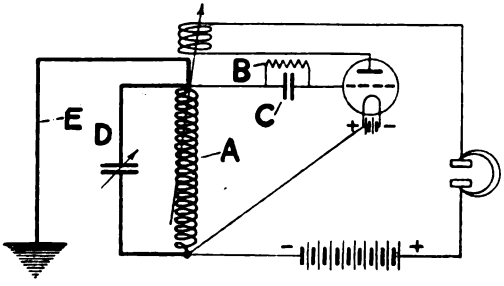
[R008

RECEIVER WITHOUT AERIAL.

(*Application dates, January* 11 *and March* 23, 1923.)

Patent No. 217,259 of D. S. B. Shannon is intended to cover a regenerative or super-regenerative receiver wherein the grid end of the grid tuning



inductance is connected to earth, the lower end being connected to the positive terminal of the L.T. battery and the negative terminal of the H.T. battery. The grid-condenser C is of larger capacity than usual and may have a capacity between ·0005 and ·02m.F, while the grid-leak B has a low value of about 100 000 ohms. It will be seen that the grid of the detector has normally a slight positive bias. Presumably the capacity of the set to earth has the necessary aerial effect.

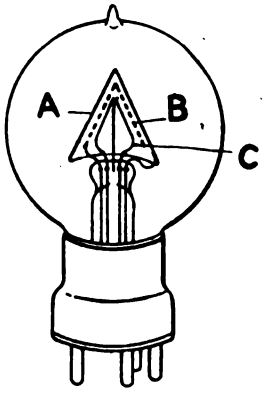
INTERFERENCE FROM IGNITION SYSTEMS.

(*Application date, February* 10, 1923.)

Reception of wireless signals on cars or aeroplanes may be seriously interfered with by short-wave damped oscillations set up in the ignition leads by the discharges at the sparking plugs in the engine. Patent No. 217,270 of V. Kulebakin covers a simple but ingenious method of eliminating these disturbances. The leads from the magnets to the sparking plugs are made of such high resistance as to be aperiodic from an H.F. point of view while being still sufficiently conductive for ignition purposes. Each discharge is thus made dead-beat and no oscillatory currents are produced. The ignition leads may, for instance, be oxidised iron chains, thus introducing a large number of contact resistances in series.

VALVE CONSTRUCTION.

(*Application date, January* 4, 1923.)

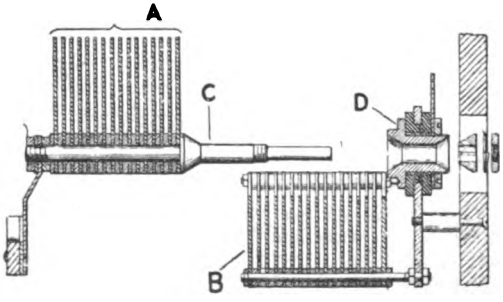


In Patent No. 217,256 the British Thomson-Houston Co., Ltd., cover the use of conical electrode elements. The anode A and grid B are coaxial cones while the filament C may take the form of an inverted **V** or a conical spiral. The object is to provide a dome-like electrode structure while at the same time keeping the electron-emitting cathode symmetrical with respect to the other electrodes.

CONDENSER CONSTRUCTION.

(*Convention date, February* 1, 1923.)

The main purpose of the construction illustrated is to reduce the labour of assembly by making it possible to introduce or withdraw the moving plates and shaft A as a complete unit without inter-



fering with the fixed plates B. This is accomplished by discarding the bottom end-plate and bearing and having one substantial conical bearing C D at the top. (Patent No. 210,771, E. S. Miller.)

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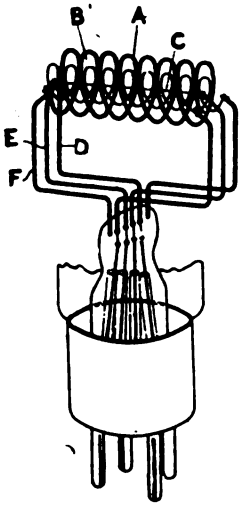
SPIRAL ANODE VALVE.

(*Application date, March* 19, 1923.)



Patent No. 217,647, held by T. W. Lowden, covers a thermionic discharge tube having an anode A consisting of a spaced helix of wire surrounding the cathode C, no parts of the helix being short-circuited. Electrical connection from the lead-in wire is made to one end of the anode spiral through one of the supports. This type of construction is used also in the Penton and Thorpe valves, and its exact advantages have always seemed to us rather problematical. Perhaps, however, it is simply to avoid earlier valve patents, which usually specified an anode in the form of a cylindrical sheet.

EVACUATING WATER-COOLED POWER VALVES.

(*Application date, February* 14, 1923.)

In the process of pumping hard power valves it is desirable to raise the anode to a high temperature in order to release occluded gases. This involves a difficulty with valves employing a metal anode which also forms part of the envelope and which is sealed to a vitreous portion of envelope, because the seal will be destroyed if a high temperature is applied to it. E. Y. Robinson in Patent No. 217,273 employs means for cooling the metal envelope in the neighbourhood of the seal so that although the rest of the metal envelope may be raised to a high temperature the seal itself is protected.

EARTHING WATER-COOLED ANODES.

(*Application date, March* 15, 1923.)

One of the difficulties with valves having water-cooled anodes is the insulation of the water supply if the anode has a high potential to earth. The obvious alternative, covered by E. Y. Robinson's Patent No. 217,327, is to earth the anode and allow the other electrodes to assume a high potential. If this is done the cooling water may be supplied directly from the water main. The specification describes how the anode may be made the earthed electrode in the case of various single- and polyphase rectifiers and oscillators. We should hardly have attributed sufficient originality to the idea to be the subject of a patent.

VALVE PUMPING PROCEDURE.

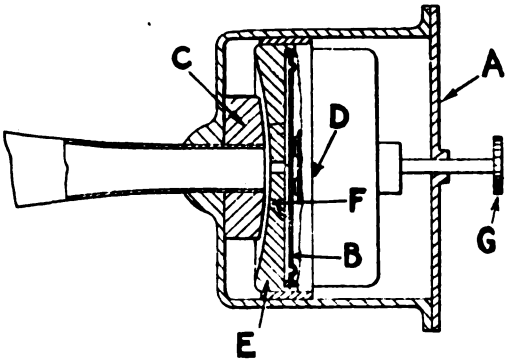
(*Application date, February* 22, 1923.)

It has been common practice for some time to perform the welding of thermionic valve electrodes in an atmosphere of hydrogen gas. The object of this is to prevent the oxidisation of the metal parts and the occlusion of oxygen in the metal itself, as occluded oxygen retards the pumping process and is detrimental to the action of hard valves. In their British Patent 216,207 Messrs. C. Seymour, B. Hodgson, H. G. Hughes and T. E. Goldup, of H.M. Signal School, carry preliminary precautions further by assembling the internal parts of the valve in an atmosphere of some inert gas such as nitrogen. The presence of nitrogen within the bulb is particularly advantageous in those operations where the glass is being subjected to the blowpipe flame. The assemblage in a nitrogen atmosphere is preferably followed by a baking in an atmosphere of hydrogen prior to pumping. The inventors state that with silica valves employing tungsten and molybdenum elements the necessary period of bombardment during exhaustion is materially reduced by the preliminary procedure referred to.

AIR DAMPING IN LOUD SPEAKERS.

(*Application date, January* 24, 1923.)

We are most of us familiar with the result of using an ordinary earpiece in conjunction with a horn as a loud speaker. As soon as we load it up sufficiently to obtain real loud-speaker strength the amplitude of vibration of the diaphragm becomes excessive and it tends to rattle against the pole-pieces or the cap of the receiver. Most properly-constructed loud speakers have larger and stouter diaphragms so that ample sound energy is obtained from a reasonably small amplitude of movement of the diaphragm. In their British Patent 214,718, however, P. L. Wostear and R. H.



Billingsley describe a construction of loud speaker which permits the use of the headphone size of diaphragm without undue distortion or loss of volume. The invention consists essentially in having a cap E very close to the diaphragm B, the cap E being perforated by a small central hole E and other small holes F surrounding it. This restriction of the air in front of the diaphragm

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results in a damping which prevents the diaphragm from taking up excessive amplitudes. At the same time the inventors state that owing to the enhanced intensity of the air displacements at the hole D a large volume of sound is produced. Another feature of the invention is that a screw G is provided by means of which the receiver may be moved longitudinally in the outer case A to allow an adjustment of the gap between E and the washer C, thus allowing an adjustment of the air-damping and the volume of sound emitted.

ATMOSPHERIC ELIMINATION.

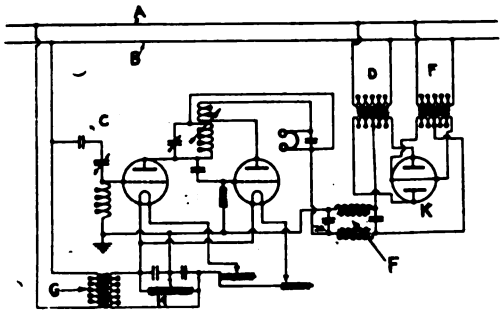
(*Convention date, February* 16, 1923.)

A method for receiving morse signals through atmospherics is described in Patent No. 211,512 of Marconi's Wireless Telegraph Co., Ltd., and R. H. Ranger. The main feature of the invention is the use of a limiting device which is saturated or paralysed by the received marking signal, or the signal plus atmospheric disturbances, but which is not paralysed by the disturbances alone during the spacing intervals. Thus the indicating device is operated by inverse morse or spacing signals. As atmospherics are of short duration and not persistent the limiting device is not ever saturated for any appreciable part of a spacing interval by the atmospherics alone. Means are described for re-inverting the inverse morse signals passed on by the limiter so that intelligible signals are produced at the final indicating device.

RECEIVERS OPERATED ENTIRELY FROM SUPPLY MAINS.

(*Application date, February* 12, 1923.)

J. Robinson and W. H. Derriman have patented "a wireless receiving set adapted to be applied to an electric light or power system so that the

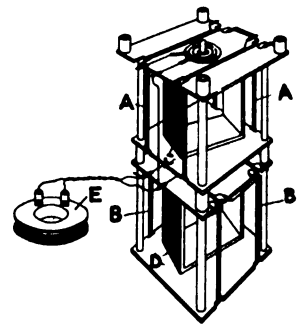


latter forms an aerial for the receiving set and supplies power for operating the receiver." We show a figure illustrating the arrangement of a set adapted to work off A.C. mains. A and B are the main wires which supply the filament lighting transformers E and G and the plate-supply transformer D. K is a full-cycle rectifying valve whose output, after smoothing with the usual combination of condensers and chokes at F, is fed to the anodes of the receiving valves. The usual form of earth connection is used, while one of the supply wires is used as an aerial, connection being made through the condenser C which keeps out the low-frequency A.C. without offering any material impedance to the H.F. currents to be received. H is the usual potentiometer arrangement, which is necessary when A.C. is used for filament heating, the purpose of which is to maintain the mean grid-filament potential constant as far as the low-frequency A.C. component is concerned.

The claims of the patent are very broad, but we cannot trace any single feature in the circuit shown which was not familiar to us before the date of application. The use of the mains as aerial through a series condenser has been common knowledge ever since the "Ducon" adapter made its appearance, and other details on the A.C. side must have been described in numerous periodicals during the last two years. The use of A.C. on the filaments of present type of receiving valve will never be a complete success, however, as there is always a considerable hum due to the low thermal inertia of the filaments. The specification referred to also describes a set adapted to be entirely operated off D.C. mains by the now well-known arrangement of potentiometers and resistances. (British Patent 215,455.)

COMPENSATION OF ERRORS IN DIRECTION FINDERS.

(*Application date, March* 23, 1923.)



C. Seymour and C. E. Horton describe in Patent No. 217,668 a means of compensating quadrantal errors such as may occur in D.F. receivers of the Bellini-Tosi type. Instead of only one search coil for both field coils there are two search coils C and D which rotate within their own sets of field windings A and B. The search coils C and D rotate together and their magnetic axes are parallel while the field coils A and B are at right angles to each other. The field windings A and B are connected respectively to two loop aerials at right angles. The windings C and D are in series with each other and are connected to the input of the receiver. The constants of either field winding may be adjusted independently of the other to compensate for any error. For instance a variable inductance E may be shunted across one of the coils.

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EXPERIMENTAL WIRELESS
& The WIRELESS ENGINEER

VOL. II. NOVEMBER, 1924. No. 14.

Editorial Views.

The Amateur's Position.

WE have naturally been watching with interest the position which has been developing as to the amateur transmitter. It seems likely that before long affairs may reach a difficult stage. We have heard, and seen, some evidence that the Post Office has during the last few months altogether altered its attitude—previously a very considerate one.

The Radio Society apparently can find no reason whatever for this change, and accordingly is somewhat resentful. In fact it is preparing, we gather, to fight the P.M.G. in the Courts as to the legality of some of his actions in the matter. It is possible that its efforts may meet with success, but we cannot help feeling doubtful. It has always seemed to us that the whole intention of all the legislation which is in existence on the subject of wireless, is in reality that of placing the whole of the science entirely within the power of the P.M.G. Until recently, in fact, this view seems to have been generally held.

About a year ago there was much activity in the daily Press about receiving licences, on the ground that the Wireless Telegraph Act only dealt with transmitting. It was claimed that the P.M.G. had no right at all to deal with receiving, going by the words of the Act.

But it was realised soon that talk of this kind was useless, for if it were proved that the Act did not entitle the P.M.G. to control reception, another would soon be passed that would! In fact, the general official opinion, right or wrong, is that the P.M.G. shall have a complete control of wireless.

Suppose now the R.S.G.B. succeed in proving that the P.M.G. has exceeded his legal rights, and that he cannot refuse transmitting licences at will. The Society would next have to be prepared to fight a new Wireless Telegraph Bill which might soon be introduced to give back to the P.M.G. the powers he had lost in the Courts. And it must be remembered that the fight would be a lonely one. The three Services, the shipping and other commercial companies, and the broadcasting interests have no particular friendship for the amateur, and the P.M.G. has only to plead that their interests render it necessary for him to restrict amateur experimental work to get ample and influential backing for such a course. We feel that the R.S.G.B. would do better to start an investigation into the personnel of the G.P.O. What is the reason of this change of official attitude? Who is behind it? What is the real motive? If they could find the answer to these questions the whole matter could quite probably be straightened out.

The Experimenter's Claims.

Perhaps our readers do not realise how little respect official and commercial circles have for the amateur. In this case they will get rather a shock if they read pp. 47 *et seq.* of Capt. P. P. Eckersley's new book on broadcasting.*

Here he is dealing with the question of amateurs jamming broadcasting. He explains how the amateurs claim that they do much towards furthering the science of

* *Captain Eckersley Explains.* Publishers, Wireless Press, Ltd.

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wireless. Then he discusses that claim, and says :—

. . . in my opinion the amateur has not materially, as an amateur, contributed towards the progress of the science. Where he has contributed is in getting such a knowledge by his own efforts that he eventually becomes a professional, and when he becomes a professional . . . he then becomes a valuable man and makes advances.

This is a strong statement, and by one who is well acquainted with amateur work. And there is enough truth in it to make it dangerous unless it is tackled. Let us take as an instance the recent advance in short-wave work at long ranges. The general opinion is that nearly all the spade-work in this branch was inaugurated by amateurs. Now Capt. Eckersley was at one time associated with the research department of a great commercial organisation, and he would probably reply that he knows of short-wave work by them that was better than that of the amateurs. But now we arrive at the crux of the matter.

That professional research, if it was done, was done for the advancement of one commercial organisation, not for the good of wireless. It might be patented, it might be used secretly, it might be buried to avoid making obsolete large stations designed for long waves. Curious things do happen in that way.

On the other hand, when the amateurs find out things, since they are working in the scientific spirit, they publish their work immediately. We therefore reply to our friend Capt. Eckersley that, even if the professionals discover ten facts to the amateur's one, the amateur may yet have rendered the bigger service to the science in general, for he makes his one fact available to all.

Real and Sham Experimenters.

Returning for a moment to our consideration of the transmitting position, the one fact which shows up most plainly is not that licences are being unfairly withheld, but that they have been too freely given to the unworthy. There is far too much transmission which is not in the nature of serious investigation, but is quite obviously simply a pleasant hobby for the young.

At present, a licence is granted mainly on a detailed programme of experimental work to be done—a programme which is often allowed to slide completely when the licence is once obtained, and which is at the same time very cramping to the real worker. It would seem far preferable to demand less programme and more qualifications—in fact, a stiff practical examination. At the same time the ridiculous position of a licence for artificial aerial work could be abolished.

Calibration.

We regret to inform our readers that our calibration department must be closed for a month. Instruments have been coming in faster than we can deal with them just lately, and we are anxious to clear up the arrears. When this has been done, we shall be sending our standards to the N.P.L. for their periodical check, after which we shall again be ready to receive apparatus. It is hoped that this programme will be completed within the month; but in any case a definite announcement will be made in our next issue.

Esperanto.

Everyone seems to be agreed that since the American Radio Relay League has settled upon Esperanto as the auxiliary language for international work, the best thing is to follow suit. In doing so, of course, one also adopts the A.R.R.L. view that the decision is made without prejudice to the merits of other such languages, but simply because Esperanto, being the most used of them, is *ipso facto* the most useful at present.

Hitherto, most of us have been content to sit down and say piously "an excellent idea! I hope all the other fellows will learn it at once." But this attitude does not seem likely to be immediately helpful, so we propose to go somewhat further. In an early issue we hope to publish a compact account of Esperanto, sufficient to act as a working grammar, and we propose to keep up, month by month, a small corner devoted to the language. We also hope to print a complete English-Esperanto dictionary of wireless terms, which has already been prepared as a French dictionary by Dr. Corret.

With these at hand, we can at any rate say that no reader of E.W. & W.E. has any excuse for continuing to put his continental fellows to inconvenience by insisting on their working him in English.

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The Arrangement of Wireless Books and Information. [025·4

Part II: R100—General Principles.

This instalment is preceded by some references omitted in our last issue.

Below we print a further instalment of the B.S. extension of Dewey, including the whole of R100.

Before proceeding to the actual tables, we wish to give the references for some items in our last month's issue, from the titles of which the numbers were inadvertently omitted. They are as follows :—

PAGE.	ARTICLE.	REF. NO.
31	G.2KW	R612
41	Low-tension Discharge Tubes	621·327
48	Crystals and Crystal Testing	R374·009
55	Amateur Transmission	R113·1
55	Transformers	R342·700·9

The B.S. Extension (*continued*).

R100 **General Principles and Theory.**

As explained in the summary in our last issue, this heading is not for matters of detailed or practical design. It may happen that some item to be classed apparently includes both theory and practice. In this case, one can only decide by considering (*a*) are the practical portions really only examples to help in explaining the theory? or (*b*) are the theoretical portions really only offered to help in understanding the practical design?

Type (*a*) will obviously be classed here, and type (*b*) under R300.

Note that R100 is only for general or "pure" theory: the theory of any system or application will go under R500 or R600: look at the headings of other divisions in the summary before placing items here. The numbers from R100 to R110 are divided like R000.

R110 Wave motion, ether waves, radiation, etc.

- R111 Electro-magnetic theory in general. (Clerk-Maxwell's laws, etc.)
- R112 Radiation, absorption by receiving aerial, etc. This deals with the transition from aerial current to free wave, and *vice versa*.
  - R112·1 Radiation.
  - ·6 Absorption (*i.e.* reception).
- R113 Free wave phenomena.
  - R113·1 Fading and allied phenomena.
  - ·2 Daily and seasonal variations in signals.
  - ·3 Directional effects (not intentional directional work, which is under R115, R125 and R500).
  - ·4 Ionisation and Heaviside layer effects.
  - ·5 Meteorological effects.
    - ·55 Tropical work.
  - ·6 Reflection, diffraction, refraction, etc.
  - ·7 Range, intensity formulæ.
  - ·8 Effects of eclipses and other cosmic phenomena.
  - ·9 Wave front angle.

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R114 Atmospherics.
This section is for information on atmospherics themselves : methods of preventing interference are R430.
R115 Directional properties in general.
Aerials specially designed for directional work are found under R125.
R116 "Wired wireless," *i.e.*, high frequency work on transmission lines.

R120 Aerials and their theory.

This section covers all forms of collector, even the picking up of signals in the tuning coils themselves.

R121 Aerial-earth systems, of the ordinary elevated type.
R122 Aerial-counterpoise systems. Such systems are often earthed also. Their distinguishing feature is that most or all of the current passes to the counterpoise.
R123 Ground and underground aerials, such as Beverage, etc., also aerials in mines, etc. Underground transmission as a whole is under R536.
R124 Frame aerials, for general work.
R125 Directional work.
R125·1 Direction finding aerials, *i.e.*, Bellini-Tosi, frame, etc., for reception from a particular direction.
R125·6 Directive aerials, *i.e.*, double phase-regulated systems and others for transmitting in a particular direction.
R126 Earth connections and earths.
*R126·5 Counterpoise theory.
R127 Aerial constants : the theory and calculation of aerial capacity, inductance, resistance, etc. For Measurement, see R200.
*R127·1 Natural wave-length.
* ·2 Capacity.
* ·3 Inductance.
* ·4 Resistance.
R129 Special types of aerial not covered above.

R130 Valve theory. For design and practical construction of circuits, see R300.

R131 Characteristic curves, general properties.
R132 Amplification, general action.
R132·1-3 Intervalve, input and output couplings for amplification.
R132·1 Inductive : by transformers or chokes.
·2 Capacitative.
·3 Resistance.
*R132·8 Reflex amplification.
R133 The valve as oscillator : general idea only ; details are in R344.
R134 Valve detection.
*R134·1 Anode rectification.
* ·2 Grid rectification.
·4 Retroaction, reaction.
·45 Super-regeneration.
·7 Heterodyne reception.
·75 Frequency conversion, supersonic heterodyne.
R135 Modulating.
R136 Input Impedance.
R137 Output impedance.
These two divisions should receive material dealing with the connection between valve design, etc., and impedance. The effect of such impedance on amplification should go under R132.
R138 Emission : filament design ; ionisation.
R139 Other matters.

R140 The theory of circuits, and alternating currents in general.

R141 Constants, etc., of simple circuits.
The arrangement here is not strictly logical, for R145 should come first, as a natural introduction.
R141·1 Variation of current with frequency.
·2 Resonance.
·3 Impulse excitation and free oscillation.
R142 Coupled circuits.
R142·1 Direct coupling.
·3 Inductive coupling.
·5 Capacity coupling.

*** These sub-divisions are proposed by us as a tentative further extension.**

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R143 Damping and decrement.
R144 Resistance.
R145 Reactance.
R145·3 Inductive reactance.
·5 Capacitative reactance.
R146 Free harmonics.
R147 Beats.
This, as also R148 and R149, is not concerned with methods, but only with the theory of such currents and the conditions in circuits carrying them.
R148 Modulation.
R148·1 Distortion.
R149 Rectification.

R150 The generation of high frequency currents.
This is reserved to methods other than the Valve Oscillator, which is covered in R133.
R152 Spark apparatus.
R153 Arcs.
R154 H.F. alternators.
R156 Static frequency transformers.

R160 Receiving apparatus, general considerations.
Reserved for matters applicable to all forms of apparatus.
R161 Sensitivity.
R162 Selectivity.

R190 General principles not covered above.

An Easy Way to Calculate Circuits.

By P. K. Turner. **[R145**

Showing how, with nothing beyond simple arithmetic, one can find the Reactance, Impedance, etc., of any circuit, for radio or audio frequencies.

THE writer believes that there are many wireless amateurs, doing in some cases quite advanced work, who are handicapped by not being really familiar with the work of calculating and designing A.C. circuits. In most cases they are (in theory) quite conversant with the meanings of such words as Inductance, Capacity, Reactance, Impedance; but if they are called upon suddenly to understand and express their exact effect in a circuit, they are rather at a loss—simply through lack of habitual contact with them in a quantitative way.

Yet the work is not difficult. No "higher mathematics" need be involved: the work is just one degree more complicated than Ohm's Law, and for any student in wireless it is an absolute necessity that he should be able to handle it just as easily.

Just as an example, let us put three questions:—

1. Consider a crystal set. The aerial flattens the tuning because it has a resistance of (say) 20 ohms in series with the tuned circuit. The crystal does so because it has an effective resistance of (say) 5 000 ohms across the tuned circuit. Which really makes most difference?

2. A "tuned anode" circuit is known to be useful because to H.F. currents it acts as a high resistance. How high *is* its apparent resistance?

3. In a 1-valve reaction set we find a fixed condenser across the phones to by-pass the H.F. component while stopping the L.F. How big should it be?

The purpose of this article is to show how to answer such questions by simple arithmetic

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with an occasional touch of equally simple algebra, plus one device that may be new to the beginner, but is quite easily learnt.

We should like to emphasise the fact that these calculations are equally applicable to all frequencies, both radio and audio. But they are less accurate at radio frequencies, for they depend upon our knowing the capacities, inductances, resistances, etc., that are to be used, and we are not always certain what these are for high frequencies—we will deal further with this later on.

Since we are going to do without high-brow mathematics, we must take a great deal for granted. Firstly, we shall be dealing with alternating currents, and for the benefit of the advanced we will explain that we shall assume "pure sine wave" throughout. For the beginners, we will explain that since an alternating current is continually varying, there are three values of it which might be dealt with: The "instantaneous" value—the actual varying amount from moment to moment—which we shall *not* touch; the maximum current; and a form of average current called the r.m.s. value. The latter is defined by being the current as read on a hot-wire meter: it is ·707 times the maximum. Exactly the same three voltages will be found. The calculations which follow will apply to either maximum or r.m.s. values, *so long as we stick to one or the other for any complete calculation.*

The Three Components.

Just to clear our ideas, we will devote a few words to the three components of our circuits.

Resistance.—This is the same for direct and alternating currents (except for high frequencies). Everyone knows that it is expressed by dividing voltage by current: *i.e.*, if six volts (direct, maximum, or r.m.s.) applied to something causes $1\frac{1}{2}$ amps. (direct, maximum, or r.m.s., to correspond), then that something has 4 ohms resistance.

We usually call voltage E, current I, and resistance R, and we abbreviate volts, amps, and ohms to V, A, and O, so we express the law as

$$R = \frac{E}{I},$$

and the particular example as

$$R = \frac{E}{I} = \frac{6V}{1{\cdot}5A} = 4O.$$

Inductance offers no obstacle at all to direct voltage. Under alternating voltage, it passes a current which lags behind the voltage. The ratio of voltage to current is called the REACTANCE—sometimes INDUCTIVE reactance—to distinguish it from the other sort described below. The Reactance of a given Inductance depends on the frequency: it is not constant (as resistance is except for very high frequencies). The method of calculating reactance is given below. Do not confuse "Reactance" with "Reaction."

Capacity offers a complete interruption to direct voltage. Under alternating voltage it passes a current which leads in front of the voltage. We grant readily that this seems absurd: but it is true. For proof consult a mathematician. Better still, take our word for it. The ratio of voltage to current is in this case also called REACTANCE—sometimes CAPACITATIVE or capacity reactance to distinguish it from the Inductive variety mentioned above.

Inductance is measured in Henries (H) or Microhenries (μH): 1 000 000 μH = 1H. It is usually represented for short by the letter L.

Capacity is measured in Farads (F) or Microfarads (μF) or Picofarads—sometimes called Micromicrofarads ($\mu\mu$F).

$$1\,000\,000\mu\mu F = 1\mu F;$$
$$1\,000\,000\,000\,000\mu\mu F = 1\,000\,000\mu F = 1\ F.$$

(These large numbers are awkward. We usually abbreviate by saying

$$10^{12}\mu\mu F = 10^{6}\mu F = 1F.$$

The small figure, called the "exponent," represents the total 0's in the number. To multiply two such numbers, add the exponents; to divide, subtract. A negative exponent means a decimal, with one 0 less than the exponent; *e.g.*,

$$10^{-4} = {\cdot}000\,1 = \frac{1}{10\,000})$$

Capacity is usually represented for short by the letter C.

Reactance is measured, like resistance, in ohms. It is represented by X. If we want to keep the two sorts distinct we call them X_L and X_C.

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Numerical Values.

Now to find the *numerical* value of reactance. We emphasise "numerical," for there is something else, as we shall see. Both kinds of reactance depend on frequency, which we shall refer to as f. But, as a matter of fact, f almost always appears multiplied by 6·283 2 (2π to the initiated), and so we usually denote the product $6{\cdot}28f$ by the one Greek letter ω ("omega").

To find the numerical value of Inductive Reactance, multiply Inductance in Henries by ω:—

$$X_L \text{ (ohms)} = \omega L \text{ (Henries)} = \frac{\omega L}{10^6} \ (\mu H).$$

To find the numerical value of Capacity Reactance, multiply Capacity in Farads by ω, and divide 1 by the product.

$$X_C \text{ (ohms)} = \frac{1}{\omega C} \ (F) = \frac{10^6}{\omega C} \ (\mu F).$$

Just as an example, take $L = 200\mu H$ (about the usual 50-turn coil) and $C = {\cdot}000\,5\mu F$ at 377 metres. We know that we convert wave-length (λ) to frequency by

$$f = \frac{3 \times 10^8}{\lambda}$$

$$\text{In this case } f = \frac{3 \times 10^8}{\lambda} = \frac{3 \times 10^8}{377} = 795\,000$$

$$\text{and } \omega = 6{\cdot}28f = 4\,996\,000.$$

(It would have been 5×10^6 exactly if we had been more accurate in calculation—that is why we settled on 377 metres !)

$$\text{Then } X_L = \frac{\omega L}{10^6} = \frac{5 \times 10^6 \times 200}{10^6} = 1\,000 \text{ ohms.}$$

$$X_C = \frac{10^6}{\omega C} = \frac{10^6}{5 \times 10^6 \times {\cdot}0005} = \frac{1}{{\cdot}0025} = 400 \text{ ohms.}$$

Now suppose we have a resistance of 500 ohms in series with X_L. One is tempted to say that the whole circuit has a resistance or reactance of 1 500 ohms.

But it hasn't.

First, the result is not 1 500 ohms. Second, it is neither a resistance nor a reactance.

Another word is used to describe this mixture of both: it is called IMPEDANCE, is measured in ohms, and is usually represented by Z. As to its amount, there is a discrepancy, due (we will not attempt to explain why in this article) to the fact that the reactance causes a lagging current while the resistance does not. They must be combined in this way:—

$$Z^2 = R^2 + X^2,$$

or, in words, square the resistance and the reactance, add their squares, and the square root of the sum is the impedance. In this case,

$$\begin{aligned} R^2 &= 250\,000 \\ X^2 &= 1\,000\,000 \\ \hline Z^2 &= 1\,250\,000 \\ Z &= 1\,118 \end{aligned}$$

Dealing with Complex Circuits.

Now the above method is all right as far as it goes: but it does not go far enough. We should be landed in hopeless difficulties in dealing with parallel or complex circuits. For these we want some method of keeping all the leading or lagging currents and voltages apart from the others throughout the calculation. For example, suppose we had an R and an X in series, and then put in series another pair. It would not be correct to add the Z found from the first to that found from the second set. We must rather add the R's and then the X's, and then find the final Z.

The best method of distinguishing the two is to make use of the symbol j. This has a highly difficult and special meaning really —it is a sort of pass-word to the inner circles of the high-brow—but we will forget that. We will adopt the following plain rules; bear with us while we explain them: their usefulness will be shown later.

When we get several expressions, such as $10+j$, $120\,000+j$, $\frac{1}{6-3j}$, etc., to deal with, we must always keep apart the "j" quantities, as shown below.

$j^2(j \times j)$ is equal to -1 (from which it follows that $\frac{1}{j} = -j$).

To add (say) $6+4j$ to $8-3j$, we add 6 and 8, and then add 4 and -3, getting $14+1j$.

To multiply the same two, multiply separately by each part:—

$$\begin{array}{l} 6+4j \\ 8-3j \\ \hline 48+32j \\ \quad -18j-12j^2 \\ \hline 48+14j+12 = 60+14j. \end{array}$$

The $+12$ follows, for we have already stated that $j^2 = -1$,

therefore $-12j^2 = -12 \times -1 = +12$.

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To divide, it is necessary to get rid of the j in the denominator. We do this by a neat trick. Take, for instance, the undoing of the last sum: divide $60+14j$ by $8-3j$. We multiply both top and bottom by $8+3j$, *i.e.*, the bottom with one sign changed. Thus

$$\frac{(60+14j)\,(8+3j)}{(8-3j)\,(8+3j)}=$$

$$\frac{480+112j+180j-42}{64-24j+24j+9}=\frac{438+292j}{73}$$

$=6+4j$, by simple division.

The full Reactance Expressions.

Now to employ the magic j in circuit calculations we must make a slight addition to our expressions for reactance. Instead of the values already given, which were called "numerical values" ($X_L=\omega L$, $X_C=\frac{1}{\omega C}$) use the following, which we will call, for want of a better name, "full expressions."

THE FULL EXPRESSION FOR INDUCTIVE REACTANCE is

$$X_L=j\omega L.$$

THE FULL EXPRESSION FOR CAPACITY REACTANCE is

$$X_C=-\frac{j}{\omega C}.$$

Lastly, these full expressions, either alone or when combined with resistances to form

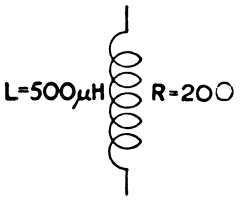

Fig. 1.

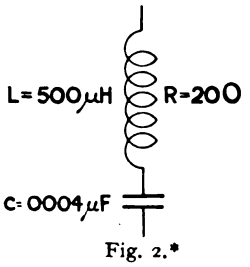

Fig. 2.*

impedances, can be combined in series or parallel just as simple resistances: thus if we have several impedances Z_1, Z_2, Z_3, etc., all in series, the total impedance Z is given by

$$Z=Z_1+Z_2+Z_3, \text{etc.},$$

and if they are in parallel,

$$\frac{1}{Z}=\frac{1}{Z_1}+\frac{1}{Z_2}+\frac{1}{Z_3}, \text{etc.}$$

Thus, take Fig. 1, at a wave-length of 942 metres ($\omega=2\times10^6$)

$$X_L=j\omega L=1\,000j.$$
$$Z=20+1\,000j.$$

Now add a condenser of .0006μF, in series, as in Fig. 2,

$$X=-\frac{j}{\omega C}=-\frac{10^{10}j}{2\times10^6\times6}=-833j$$

total $Z=20+1000j-833j=20+167j$.

What does this mean? A resistance of 20O with a reactance of $+167j$. Since this is positive, it represents an inductance. We have, then,

$$X_L=j\omega L=167j, \text{ or } L=\frac{167}{\omega}=88\mu H.$$

Thus *at this wave-length* this combination of 500μH, 20O, and .000 6μF could be replaced by an inductance of 88μH with a resistance of 20O; as we should expect, the condenser has partly neutralised the inductance.

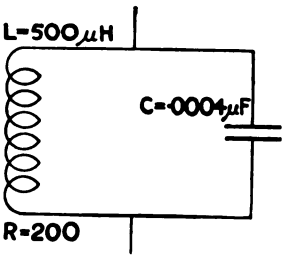

Fig. 3.*

If we wish to find the total impedance of the circuit, combining the resistance and reactance, we do it thus: square the resistance, square the reactance (neglecting j), add the squares, and take the square root. In this case—

$$Z=20+167j.$$
$$Z^2=400+27\,900=28\,300.$$
$$Z=168{\cdot}3 \text{ ohms}.$$

Remember that this can only be done when the impedance has been reduced to its final form of one resistance and one reactance in series. The two squares are always *added*, even if the reactance is a negative one.

Now suppose that with the same coil we added the condenser in parallel, as in Fig. 3. We have

$$\frac{1}{Z}=\frac{1}{Z_1}+\frac{1}{Z_2}=$$

$$\frac{1}{20+1\,000j}+\frac{1}{-833j}=\frac{1}{20+1\,000j}-\frac{1}{833j}$$

Multiplying up the fractions, we have

$$\frac{1}{Z}=\frac{833j-20-1\,000j}{833j\;(20+1\,000)}$$

$$=\frac{-20-167j}{833\,000+16\,700j}$$

* Note: the condenser should be ·000 6μF.

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Turning it upside down, and multiplying top and bottom by —1,

$$Z = \frac{833\,000 - 16{,}700j}{20 + 167j}$$, dividing top and bottom by 167, to simplify the figures,

$$Z = \frac{5\,000 - 100j}{\cdot 12 + 1j} = 100 \times \frac{50 - j}{\cdot 12 + j}$$

now dodge the bottom j

$$Z = 100 \times \frac{(50 - j)(\cdot 12 - j)}{(\cdot 12 + j)(\cdot 12 - j)}$$

$$= 100 \times \frac{6 + \cdot 12j - 50j - 1}{\cdot 014\,4 + 1} = 100 \times \frac{5 - 49\cdot 88j}{1\cdot 014\,4}$$

$$= 100(4\cdot 93 - 49j) = 493 - 490\,0j.$$

Further Examples.

Take the case of the by-pass condenser, already mentioned. Here we have, in series, the resistance of the valve—say 20 000O; the reaction coil, say 200μH, the phones, of an inductance say 5H, and resistance 4 000O, and the H.T. battery. The radio frequency is, as before, such that $\omega_r = 5 \times 10^6$, and for an audio frequency of about 1 600 we have $\omega_a = 10^4$.

In practice, the resistance of the H.T. battery can be neglected compared with that of the valve. It is probably in any case shunted by a condenser of low reactance to both H.F. and L.F.

Therefore our condenser must be such that for radio frequency its reactance is negligible compared to the rest. The reactance of the reaction coil is $\omega_r L = 1\,000$, so "the rest" is 20 000 for the valve and 1 000j for the coil.

The impedance is

$$Z_r = 20{,}000 + 1\,000j$$
$$= 1\,000\,(20 + 1j)$$

This can be expressed as,

$$Z_r^2 = (1\,000)^2\,(400 + 1),$$
$$\text{or } Z = 20\,025.$$

It will be found that any capacity reactance up to $-2\,000j$ will make a negligible difference.

This gives, as a minimum capacity (which obviously has maximum reactance),

$$C = \frac{10^6}{2\,000 \times \omega} = .000\,1.$$

On the other hand, looking at the circuit from the audio frequency point of view, the reactance of the phones is $\omega_a L = 5 \times 10^4 = 50\,000$, and their resistance is 4 000. We have

$$Z^2 = (1\,000)^2\,(50^2 + 4^2)$$
$$= (1\,000)^2 \times 2\,516$$
$$Z = 50\,160 \text{ ohms.}$$

Since the condenser is not to rob the phones of current, it must have a reactance considerably higher—say 500 000, or 5×10^5 ohms.

Thus $C = \frac{10^6}{5 \times 10^5 \times 10^4} = \frac{1}{5\,000} = \cdot 000\,2$, and as this is for a *minimum* reactance, it is a maximum capacity. So that the condenser should be between ·000 1 and ·000 2. Obviously, the usual condenser of ·001 will have a reactance of only 100 000 ohms, and will take somewhere about one-third of the current from the phones at this particular frequency.

In actual practice, the larger condenser may be preferred for telephony, for this reason: at frequencies lower than 1 600 the capacity will have higher reactance, and vice versa. It will therefore tend to rob the phones more at high frequencies and less at low, thus giving on the average a deeper and richer tone, which most people prefer.

By applying these principles any circuit, however complicated, can be dealt with.

When dealing with radio frequencies, however, remember these two points:—

1. Every coil has self-capacity, which can be treated as a condenser placed across it. The average value for coils in use at the present day is likely to be, say ·000 025μF, varying from ·000 010 to ·000 050 according to type.

2. The resistance of a coil at high frequencies has little to do with the size of wire or its direct current resistance. The resistance of the same coil goes up with frequency: the best method is to measure it, which is difficult. Barring this, a rough estimate can probably best be made by assuming the resistance to be a fixed fraction of the reactance.

It is not very wide of the mark to assume,

$\frac{X}{R} = 200$ for single-layer coils, or others specially designed for low losses;

$\frac{X}{R} = 100$ for first-class multi-layer coils;

$\frac{X}{R} = 50$ for others.

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The Performance and Properties of Telephonic Frequency Intervalve Transformers.

By D. W. Dye, B.Sc., A.C.G.I. **[R342-701**

PART III.

Herewith the concluding part of this important article, by the head of the Electrical Measurements Department at the N.P.L.

6.—Effective Ratio and Coefficient of Coupling of the Transformer.

The measurement of effective ratio of the transformer is very simple. Referring to Fig. 6 (reproduced in this instalment) the method of observation was to observe the main current as indicated on the thermo-ammeter A. From this, the potential difference on S was readily determined, and hence the primary voltage. The secondary voltage was directly observed by means of the low-reading electrostatic voltmeter. The bridge is so nearly non-inductive that the voltage on S may be computed by means of a simple multiplier from the total current with an inaccuracy much less than 1 per cent. The bridge need not be precisely balanced during this test, and, as will be seen from an examination of the curves of Fig. 21, no appreciable correction need be applied on account of the capacity of the voltmeter except at high telephonic frequency. At frequencies of the order of 3 000 cycles per second, the effective ratio of the transformer is increased by about 2 per cent. as a result of the addition of the capacity of the electrostatic voltmeter.

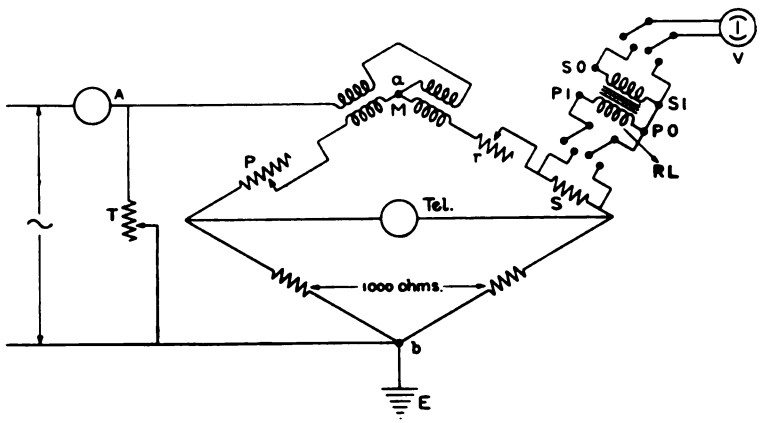

FIG. 6.

Fig. 21 shows the effective ratio of secondary to primary voltage as a function of added capacity. The curves marked A are those obtained when the capacity is added across the secondary terminals. Those marked B are for added capacity between the free ends of primary and secondary, *i.e.*, added mutual capacity. The capacities used in plotting the curves have been corrected to "total effective capacity," in order that the two sets of curves may appear in their correct relation to one another. These results represent "added capacity" + voltmeter capacity + mutual capacity or self-capacity of the winding as the case may be. When the curves are so plotted, they are seen to converge with remarkable accuracy on to the point representing the geometrical ratio of the windings, *i.e.*, 3·5. These curves show that marked increase in effective ratio of a transformer can occur as a result of adding capacity across the secondary winding or of adding mutual capacity, and that well-defined maximum ratios occur having values depending upon the frequency. The value of capacity at which the maximum occurs also depends upon the frequency.

These results were at first puzzling, for it must be remembered that the transformer is being operated in a region of frequency far beyond the resonant frequency. The latter occurs at about 2 000 cycles per second at a total effective secondary capacity of the order of 60$\mu\mu$F (shown

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by a dotted line near the ratio axis). It will be observed that no marked increase in ratio occurs at the resonant frequency. An insight into this remarkable behaviour is obtained by a simple mathematical consideration of the problem; this is given in a note.[2]

It can be shown that, if σ is the ratio of secondary to primary voltage,

$$\sigma^2 = \frac{k^2\sigma_0^2}{\left[1 + \frac{R_t}{S_2} - L_2C_2\omega^2(1-k^2)\right]^2 + \left[\frac{R_1\sigma_0^2 - L_2C_2\omega^2R_t}{L_2\omega} - \frac{L_2\omega(1-k^2)}{S_2}\right]^2} \quad .. \quad (34)$$

where $R_t = R_1\sigma_0^2 + R_2$.

An examination of this equation reveals immediately why σ reaches a maximum value for a frequency or added capacity far beyond the resonant frequency or self-capacity of the secondary circuit. The term $1 - k^2$ is the governing factor. If k is unity there will be scarcely any variation of σ with C_2 or ω, since the other terms involving R_1, R_2 and S_2 are small compared with unity. Owing, however, to the fact that k^2 is not quite unity, $1 - k^2$ is a small positive quantity such as 0·03. At a value of $L_2C_2\omega^2$ equal to about 30, therefore, the first bracket becomes zero, and the voltage ratio is determined only by the resistance terms in the second bracket. These can, theoretically, be made as small as we like, so that a large increase in σ is possible.

It is generally possible to neglect the terms containing S_2, unless a comparatively low resistance shunt is used on the secondary. The expression then reduces to

$$\sigma^2 = \frac{k^2\sigma_0^2}{\left[1 - L_2C_2\omega^2(1-k^2)^2\right] + \frac{1}{L_2^2\omega^2}\left[R_1\sigma_0^2 - L_2C_2\omega^2R_t\right]^2} \quad .. \quad .. \quad (35)$$

The corresponding expressions for the case of mutual capacity are somewhat more complicated, but[3] it may be shown that the effect of mutual capacity is similar to that of secondary capacity, and that the maximum value of σ will occur at almost the same frequency or added capacity in the two cases.

It is of interest to find the values of k and R or S_2 which will give values of σ agreeing with the experimental curves of Fig. 21. It will suffice to take the secondary capacity case of (35). Differentiating with respect to C_2 we find that σ (*max.*) occurs when

$$C_2\ (\sigma\ max.) = \frac{\frac{S_2+R_t}{S_2L_2}\left[L_2^2\omega^2(1-k^2)\right] + \frac{R_t}{L_2S_2}\left[R_1S_2\sigma_0^2 - L_2^2\omega^2(1-k^2)\right]}{L_2^2\omega^4(1-k^2)^2 + R_t^2\omega^2} \quad .. \quad .. \quad (38)$$

In any case except that of a poor transformer this reduces to

$$C_2\,(\sigma\,max.) = \frac{L_2^2\omega^2(1-k^2) + R_tR_1\sigma_0^2}{L_2\omega^2\left[L_2^2\omega^2(1-k^2)^2 + R_t^2\right]} \quad (39)$$

From the curves of Fig. 21 the value of C_2 is known for any particular case, so that, solving for $1 - k^2$, we shall find that

$$1 - k^2 = \frac{1 + \sqrt{1 + \frac{4R_tC_2}{L_2}\left(R_1\sigma_0^2 - R_tL_2C_2\omega^2\right)}}{2L_2C_2\omega^2} \quad (40)$$

In general we can neglect $R_1\sigma_0^2$, so that the expression for $1 - k^2$ reduces to

$$1 - k^2 = \frac{1 + \sqrt{1 - 4R_t^2C_2^2\omega^2}}{2L_2C_2\omega^2} \quad .. \quad (41)$$

In order to make our theoretical curve for σ fit the experimental one at, say, the maximum point, we must substitute the value of $1 - k^2$ back into equation (35).

Taking the approximate form of (35)

$$P^2 = \frac{\sigma^2}{k^2\sigma_0^2} = \frac{1}{\left[1 - L_2C_2\omega^2(1-k^2)\right]^2 + R_t^2C_2^2\omega^2}$$

and putting $R_t^2C_2^2\omega^2 = q^2$, we have

$$\frac{1}{P^2_{(max.)}} = \left[1 - L_2C_2\omega^2(1-k^2)\right]^2 + q^2 \quad .. \quad (42)$$

From (41) we get

$$L_2C_2\omega^2(1-k^2) = \frac{1 + \sqrt{1 - 4q^2}}{2}$$

which, on substitution in (42) gives

$$\frac{1}{P^2_{(max.)}} = \left(\frac{1 - \sqrt{1 - 4q^2}}{2}\right)^2 + q^2 \quad (43)$$

[2] See Note 2 at end. [3] See Note 3 at end.

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whence

$$q = R_t C_2 \omega = \frac{\sqrt{P^2(max.) - 1}}{P^2(max.)} \quad .. \quad (43)$$

Substituting this value of q back into (41) gives

$$1 - k^2 = \frac{1}{L_2 C_2 \omega^2}\left(1 - \frac{1}{P^2(max.)}\right) \quad (44)$$

Equations (43) and (44) enable the effective values of $(1 - k^2)$ and R_t to be determined from the co-ordinates of the highest points on the experimental curves of Fig. 21. This has been done in the case of added secondary capacity at a frequency of 2 000 cycles per second (curve A at 2000 on Fig. 21).

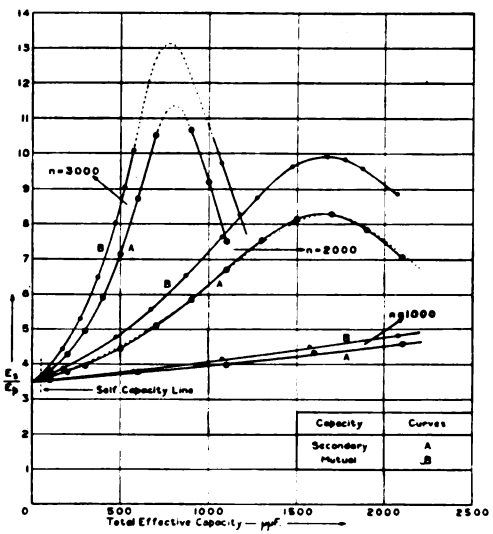

FIG. 21.

The value of L_2 required in equation (44) has been taken as 110 Henries and not 107 Henries as deduced from the line of Fig. 12. This is because the curves of Fig. 21 have been obtained for secondary voltages of the order 5, whereas the line of Fig. 12 was for a secondary voltage of 2. The circles of Fig. 18 show that L_2 increases by about 3 per cent. or 4 per cent. for an increase in magnetisation of the core corresponding to a secondary voltage of 5. Taking, then, $L_2 = 110$ Henries, and, from the curve $C_2 = 1\,650 \mu\mu F$ and σ $(max.) = 8{\cdot}30$, we find $1 - k^2 = 0{\cdot}028\,9$, $k^2 = 0{\cdot}971$ and $k = 0{\cdot}985$ and $R_t = 18\,200$ ohms. Now $R_t = R_1 \sigma^2_0 + R_2$. This quantity should, theoretically, have been 16 500 using direct-current values of R_1 and R_2. On referring back to Fig. 13, however, it will be seen that an effective value of 1 150 ohms was found for R_1. This value will give almost precisely the value of 18 200 obtained above. There are, therefore, other losses associated with the windings which cause the effective internal primary resistance to rise.

The values of $1 - k^2$ and R_t deduced above have been used to calculate theoretically the curve A at $n = 2\,000$. The line so obtained is drawn dotted on Fig. 21. The agreement with the experimental curve is remarkably good and shows that the rise in ratio with increase in frequency or with added secondary or mutual capacity is substantially in accordance with the simple theory given.

In consideration of the curves of Fig. 21 we must be careful to keep in mind the effects of added secondary capacity on effective primary impedance as indicated by the circles of Fig. 10. An inspection of these shows that the primary impedance is increased at low frequencies and decreased at high frequencies by the addition of secondary capacity.

It is advantageous to both voltage factor and ratio to add secondary capacity so long as we keep on the right hand of the circle, but for frequencies above the resonant frequency the voltage factor will suffer on account of diminished primary impedance. For example, at a frequency of 3 000 cycles per second and with a zero added secondary capacity the primary effective resistance and reactance are 20 000 ohms and —100 000 ohms respectively. The addition of $100 \mu\mu F$ to the secondary winding reduces these quantities to 2 700 ohms and —26 000 ohms respectively. We see, therefore, that above the resonant frequency the effect of secondary (or mutual) capacity is to reduce the primary impedance and hence the primary voltage factor q, where

$$q^2 = \frac{X_p^2 + R_p^2}{X_p^2 + (R_p + R_a)^2} \quad .. \quad (45)$$

On the other hand the presence of secondary capacity increases the voltage ratio of the transformer, unless the capacity is relatively enormous. For small and moderate values of capacity the voltage ratio of the transformer is given by the expression

$$\sigma = \frac{k\sigma_0}{1 - L_2 C_2 \omega^2 (1 - k^2)} \quad .. \quad (46)$$

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The amplification of the transformer is equal to the product $q\sigma$; it is of interest therefore to consider now, as the natural application of the whole of the foregoing analysis, how the amplification depends upon all the factors involved, and, in particular, upon secondary capacity and primary inductance.

7.—Voltage Amplification Curves.

The voltage amplification of a complete stage, consisting of a valve and transformer, may be written Eg_2/Eg_1 where Eg_1 is the voltage applied to the grid of the valve in front of the transformer and Eg_2 is the voltage produced on the grid of the valve beyond the transformer when connected to its secondary winding.

We have therefore $Eg_2/Eg_1 = \mu q\sigma$. This is the quantity experimentally determined by the direct method of measurement of amplification, such as that described by Mr. F. E. Smith and H. Napier.* The voltage

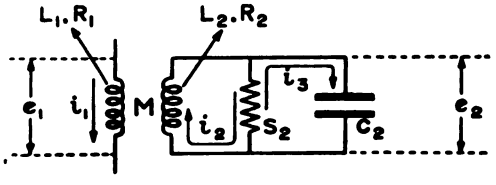

Fig. 22.

factor μ of the valve V_1 is an independent variable and does not enter into our present considerations at all, except as a mere number.

In the case of the transformer investigated here, the amplification has been directly measured using valves having a voltage factor of about 8·3 and an internal anode-voltage anode-current slope R_a of about 24 000 ohms. The curve obtained is given in Fig. 23 as a thin line. The thick line curve has been obtained by calculation of the the product of q and σ from the calculated values of X_p and R_p and the curves of Fig. 21, using the values 8·3 for μ and 24 000 for R_a. In making the calculations allowance was made for the capacity of the leads and valve connected to the secondary winding.

* F. E. Smith and H. C. Napier.—"On the Measurement of Amplification given by Triode Amplifiers, at Audible and at Radio Frequencies."—*Proc. Phys. Soc.*, 1920, Vol. 32, p. 116.

The curves fit one another very well except at the low frequency end, where the experimental curve shows higher amplification than the calculated curve. This is almost certainly due to an increase in effective inductance at frequencies below 500 cycles per second, owing to increased

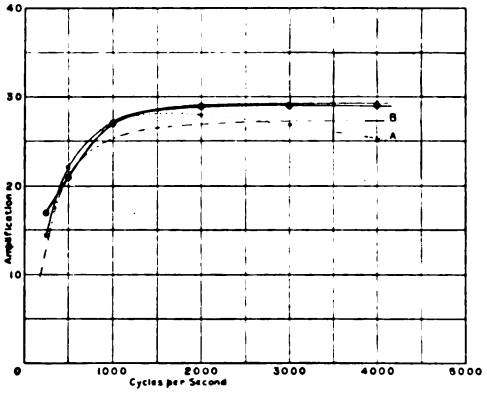

FIG. 23.

effective permeability in the iron. All the measurements become very difficult at frequencies of the order of 300 per second and the accuracy necessarily falls, but measurements of X_p and R_p at 300 indicated that the inductance was several per cent. greater than that at 500 cycles per second. In calculating the curve, the values of X_p and R_p were calculated from the deduced values of L_1, C_2, S and R_1 as obtained by analysis of the circle. For the present case the simple formulæ (8) and (10) are sufficient for the purpose, but when calculating cases in which considerable secondary capacity is present, or assumed, these formulæ are not sufficiently accurate.

It is desirable to be able to calculate various theoretical amplification curves, starting from assumed constants in the transformer, in order to gain some idea as to the desirable values of these for satisfactory performance. As an example, the theoretical case of zero secondary capacity has been taken for the transformer investigated. The curve has been plotted on Fig. 23 as the dotted line B. We see immediately that throughout the whole range of frequency shown, the amplification is lower in the absence of secondary capacity. It is generally considered that secondary capacity is undesirable, but these curves show quite definitely that a certain amount of secondary

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capacity considerably improves the performance of a transformer.

We must now consider in more detail the formulæ (21) and (22) for $R_p - R_1$ and $(L_p - L_1)\omega$, corresponding to the case given in Fig. 11 (*b*). In this case we have left out the shunt S on the primary. This quantity, however, is the main factor deciding the diameter of the circle, and must therefore be taken into account in order to obtain approximately accurate expressions for R_p and X_p.

Let R_{p1} and X_{p1} be the effective resistance and reactance of the primary as given by (21) and (22) and let this virtual impedance be shunted by a resistance S.

We then have to a close approximation

$$R_{po} = \frac{SX^2_{p1}}{S^2 + X^2_{p1}} \quad .. \quad .. \quad (47)$$

$$\text{and} \quad X_{po} = \frac{S^2 X_{p1}}{S^2 + X^2_{p1}} \quad .. \quad .. \quad (48)$$

Now, in the expressions for X_{p1} and R_{p1} the term R_2 is the only factor limiting the diameter of the circle in the absence of S across the primary. In a normal case this diameter would be so large, owing to the relative smallness of R_2, that we may neglect the effect of R_2 in substituting the values of X_{p1} and R_{p1} in the equations for R_{po} and X_{po} so long as S has a value not greater than about 10^6 ohms.

In this case $R_{p1} = 0$ and

$$X_{p1} = \frac{L_1\omega\left[1 - L_2C_2\omega^2(1 - k^2)\right]}{1 - L_2C_2\omega^2}$$

Substituting these in (47) and (48) we arrive at the final expressions

$$R_{po} = R_1 + \frac{S_1L^2_1\omega^2\left[1 - L_2C_2\omega^2(1 - k^2)\right]^2}{S_1^2(1 - L_2C_2\omega^2)^2 + L^2_1\omega^2\left[1 - L_2C_2\omega^2(1 - k^2)\right]^2} \quad (49)$$

$$\text{and } X_{po} = \frac{S_1^2L_1\omega(1 - L_2C_2\omega^2)\left[1 - L_2C_2\omega^2(1 - k^2)\right]^2}{S_1^2(1 - L_2C_2\omega^2)^2 + L^2_1\omega^2\left[1 - L_2C_2\omega^2(1 - k^2)\right]^2} \quad (50)$$

These expressions allow a series of cases to be calculated for variations of S_1, L_1, L_2, C_2 and k. If a shunt resistance S_2 is placed across the secondary, or if the grid-filament circuit of the valve imposes a load on the transformer represented by S_2, then to a close approximation this load may be transferred to the primary as an equivalent shunt resistance in parallel with S_1 and of value equal to $\frac{S_2k^2}{\sigma_0^2}$ [4]

It is obvious that the evaluation of the amplification of the transformer by calculation from its constants involves a considerable amount of arithmetic. Approximations can be made at each end of the frequency scale, but when $L_2C_2\omega^2 = 1$, and when $L_2C_2\omega^2(1 - k^2)$ is not very small, it is necessary to use the full expressions. Suppose, therefore, we have a transformer of known or assumed constants L_1, R_1, R_2, σ_0, S_1 and k: we wish to find its amplification curve when used with its primary in the anode circuit of a valve whose internal anode resistance is R_a. We calculate R_{po} and X_{po} by means of (49) and (50). Then q is determined from these and R_a, by means of (45). Finally σ is calculated by means of (46).

Note that if $L_2C_2\omega^2(1 - k^2)$ is less than about 0·25 it is necessary to use the more exact expression given in equation (35) for σ. The product $q\sigma$ gives the required amplification factor of the transformer. It is convenient to use exact values of ω for these calculations. The following typical case is given in full in order to show a convenient arrangement of the calculations so that they follow one another in a simple manner.

The case taken is one in which the constants have been assumed as follows :—

L_1 = Primary Inductance = 10H.
σ_0 = Turns Ratio = 4.
C_2 = Secondary Capacity = 50$\mu\mu$F.
S_1 = Equivalent Primary Shunt Resistance = 5×10^5 ohms.
k = Coupling Coefficient = 0·985.
$1 - k^2$ = 0·03.
L_2 = Secondary Inductance = 160H.
R_a = Anode Impedance of First Valve = 25×10^3 ohms.
R_1 = Ohmic Resistance of Primary = 1 000 ohms.

A number of theoretical cases have been worked out in order to show clearly the effect of variation of some of the constants.

The results of these calculations are given in Tables III. to V. below.

In all the cases S_1 has been taken as 5×10^5 ohms, $R_1 = 1\,000$ ohms, $\sigma_0 = 4$, and $L_2 = \sigma_0^2 L_1$.

Some of these results are plotted in Figs. 24 and 25. The curves of Fig. 24 refer to a theoretical transformer of constant

[4] See note 4 at end of Article.

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primary inductance of 20H and show the effect of various secondary capacities and also various coefficients of coupling. The curves of Fig. 25 show the effect of various values of primary inductance, and of secondary capacity. These curves show remarkable variations. It has not been possible to test experimentally the cases worked out theoretically, but a considerable number of various types of transformers on the market have been tested for amplification from time to time, and amongst the curves obtained every type shown on Figs. 24 and 25 has been found.

Amongst the transformers tested for their constants the widest variations in these have been found, thus values of primary inductance between 2 and 15H, of

TABLE II.

Calculation of Amplification Factor.

$\omega \times 10^{-3}$	1	2	3	5	10	15	20	30
$\omega^2 \times 10^{-6}$	1	4	9	25	100	225	400	900
$L_2C_2\omega^2$	0·008	0·032	0·072	0·200	0·800	1·80	3·2	7·2
$1-L_2C_2\omega^2$	0·992	0·968	0·928	0·800	0·200	— 0·80	— 2·2	— 6·2
$(1-L_2C_2\omega^2)^2$	0·984	0·936	0·860	0·640	0·040	0·640	4·84	38·4
$L_2C_2\omega^2(1-k^2)$	0·000 2	0·001	0·002	0·006	0·024	0·054	0·096	0·216
$1-L_2C_2\omega^2(1-k^2)$	1·000	0·999	0·998	0·994	0·976	0·946	0·904	0·784
$[1-L_2C_2\omega^2(1-k^2)]^2$	1·000	0·998	0·996	0·988	0·952	0·894	0·817	0·615
$(1-L_2C_2\omega^2)[1-L_2C_2\omega^2(1-k^2)]$	0·992	0·967	0·926	0·795	0·195	— 0·757	— 1·985	4·86
$L_1\omega \times 10^{-4}$	1	2	3	5	10	15	20	30
$L_1^2\omega^2 \times 10^{-8}$	1	4	9	25	100	225	400	900
$S^2(1-L_2C_2\omega^2)^2 \times 10^{-10}$	24·8	23·4	21·5	16·0	1·00	16·0	121	960
$L_1^2\omega^2[1-L_2C_2\omega^2(1-k^2)]^2 \times 10^{-10}$	0·01	0·04	0·09	0·25	0·95	2·01	3·2	5
Denom $\times 10^{-10}$	24·81	23·44	21·59	16·25	1·95	18·01	124	965
$SL_1^2\omega^2 \times 10^{-13}$	5	20	45	125	500	1 125	2 000	4 500
$SL_1^2\omega^2[1-L_2C_2\omega^2(1-k^2)]^2 \times 10^{-13}$	5	20	45	124	475	1 005	1 734	2 770
$R_{po} \times 10^{-3}$	1·2	1·8	3·08	8·6	244	57	15	4
$(R_{po}+R_a) \times 10^{-3}$	26·2	26·8	28·1	33·6	269	82	40	29
$R_{po}^2 \times 10^{-6}$	1·4	3·2	9·5	74	59 500	3 250	225	16
$(R_{po}+R_a)^2 \times 10^{-6}$	686	718	790	1 130	72 400	6 730	1 600	835
$S^2L_1\omega \times 10^{-13}$	250	500	750	1 250	2 500	3 750	5 000	7 500
$S^2L_1\omega(1-L_2C_2\omega^2)(1-L_2C_2\omega^2[1-k^2]) \times 10^{-13}$	248	483	695	992	587	— 2 840	— 9 925	— 36 430
$X_p \times 10^{-3}$	10·16	20·2	32·2	61·0	250	157·7	— 79·9	— 37·7
$X_p^2 \times 10^{-6}$	103·2	407	1 035	3 725	62 500	24 900	6 380	1 327
$Z_p^2 \times 10^{-6}$	104·6	410	1 045	3 800	122 000	28 150	6 600	1 342
$Z_t^2 \times 10^{-6}$	789	1 125	1 825	4 855	134 900	31 630	7 980	2 162
q	0·364	0·603	0·757	0·884	0·952	0·944	0·909	0·788
σ	3·94	3·94	3·95	3·97	4·04	4·17	4·36	5·03
$q \times \sigma$	1·434	2·37	2·9	3·51	3·84	3·94	3·87	3·96

TABLE III.

Amplification Factor.

ω	$L_1=5,\ \sigma_0=4,\ S_1=5\times10^5$					
	$C_2=0\mu\mu F.$		$C_2=50\mu\mu F.$	$C_2=100\mu\mu F.$		
	$k=1\cdot0$	$k=0\cdot985$	$k=0\cdot985$	$k=1\cdot0$	$k=0\cdot985$	$k=0\cdot950$
1 000	0·772	0·762	0·760	0·778	0·766	0·737
2 000	1·440	1·423	1·44	1·476	1·457	1·402
3 000	1·980	1·955	2·02	2·10	2·07	1·990
5 000	2·712	2·68	2·81	2·99	2·97	2·87
10 000	3·416	3·38	3·65	3·79	3·84	3·91
15 000	3·62	3·58	3·87	3·68	3·84	4·20
20 000	3·70	3·66	3·91	3·35	3·57	4·14
30 000	3·75	3·71	3·81	2·67	2·89	3·21

TABLE IV.

Amplification Factor.

ω	$L_1=10,\ S_1=5\times10^5,\ \sigma_0=4$			
	$C_2=0\mu\mu F.$		$C_2=50\mu\mu F.$	$C_2=100\mu\mu F.$
	$k=1\cdot0$	$k=0\cdot985$	$k=0\cdot985$	$k=0\cdot985$
1 000	1·436	1·415	1·425	1·435
2 000	2·40	2·37	2·38	2·46
3 000	2·86	2·92	2·99	3·07
5 000	3·44	3·39	3·51	3·63
10 000	3·73	3·67	3·84	3·88
15 000	3·77	3·71	3·94	3·80
20 000	3·79	3·72	3·97	3·58
30 000	3·80	3·74	3·96	3·03

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secondary capacity between 15 and 1 000$\mu\mu$F, of S_1 between $2{\cdot}5 \times 10^5$ and 12×10^5 ohms, of σ_0 between 1 : 1 and 6 : 1, thus indicating considerable differences of opinion or lack of knowledge as to what is desirable under various conditions.

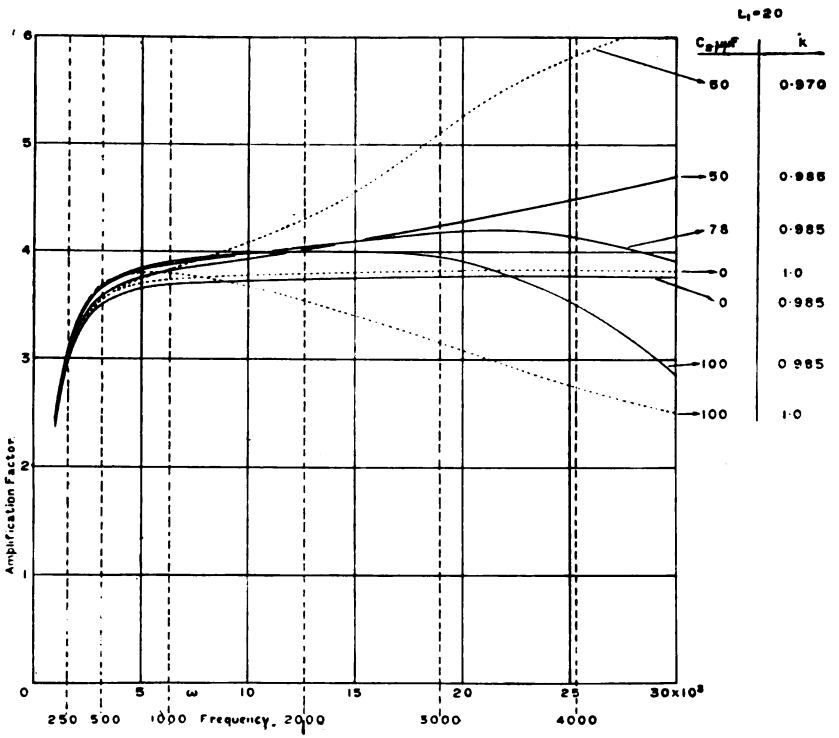

FIG. 24.

8.—Conclusions.

Further experiments are necessary in order to confirm the conclusions stated below, and it is expected that they will be somewhat modified as the result of fuller investigation; but it is believed that in a general sense the conclusions are true and that they will serve as a basis for further work.

(1) Telephonic intervalve transformers may be considered as possessed of inductance, capacity and resistances which are not very variable with frequency or voltage so long as the latter does not exceed a few volts on the secondary.

(2) The transformer behaves towards the circuit in which its primary winding is connected as though it consisted mainly of an inductance, a condenser, and a shunt resistance in parallel. Such a combination has effective reactances and resistances of which the corresponding values at various frequencies when plotted on rectangular coordinates give a curve which approximates very closely to a circle; this enables a convenient mental picture of the effective impedance over a considerable range of frequencies to be obtained.

(3) The circle diagrams enable the effects of mutual and secondary capacity and a secondary shunt resistance to be clearly visualised in a manner which allows the voltage factor of the primary winding under given conditions to be seen graphically.

(4) The grid-filament circuit of the valve to which the secondary winding of the transformer is connected, may produce profound effects on the primary impedance, according to the conditions prevailing in this circuit. In order to allow the transformer to function properly, it is usually desirable to apply to this grid a steady negative E.M.F. with respect to the filament of such value that the grid potential is never more positive than that which it assumes if left free, *i.e.*, that there can never be a thermionic grid current. Under these conditions the grid-filament circuit becomes of very high impedance, consisting of a small capacity and a resistance in series across the secondary winding; and does not seriously react on the primary impedance. Under certain conditions the grid-filament resistance may become negative in sign, and so power may be returned to the secondary winding, thus increasing the diameter of the primary impedance circle and tending to cause instability.

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The ensuing conclusions assume that the grid-filament circuit connected to the secondary circuit includes means for keeping the grid at a negative potential.

(5) The addition of a moderate shunt resistance on the secondary winding will in general produce greater stability and a flatter amplification curve than would exist in its absence. The amplification will be lowered throughout, but not seriously if the shunt resistance is not smaller than 200000 σ_0^2 ohms. A turn or two wound over the secondary and short-circuited will produce a similar improvement.

(6) No marked effects occur in either primary voltage factor or ratio of an intervalve transformer as the resonant frequency is passed, but at frequencies above this, marked increases in the ratio of the transformer may occur on account of the fact that the coupling coefficient is slightly less than unity. An effect which may be termed a ratio resonance occurs when

$$L_2C\omega^2(1-k^2)^2=1.$$

(7) The most important single property of an intervalve transformer is the inductance of the primary winding. At low frequencies (below 300 cycles per second) an amplification as great as 75 per cent. of the maximum cannot be obtained on a step-up transformer unless the primary inductance is in the neighbourhood of 20H. This value is not usually attained in practice in the writer's experience, but it should not be impracticable if a somewhat larger iron section is used and if the stampings are carefully annealed after all mechanical treatment is finished.

(8) The effects of secondary and mutual capacity are, with good approximation, interpretable in terms of one another. Thus, from the standpoint of primary impedance (and hence primary voltage ratio), a mutual capacity C_m may be considered as replaceable by a secondary capacity C_2 of such value that

$$C_2=C_m\left(1\pm\frac{1}{\sigma_0}\right)^2$$

(the sign depends upon the relative directions

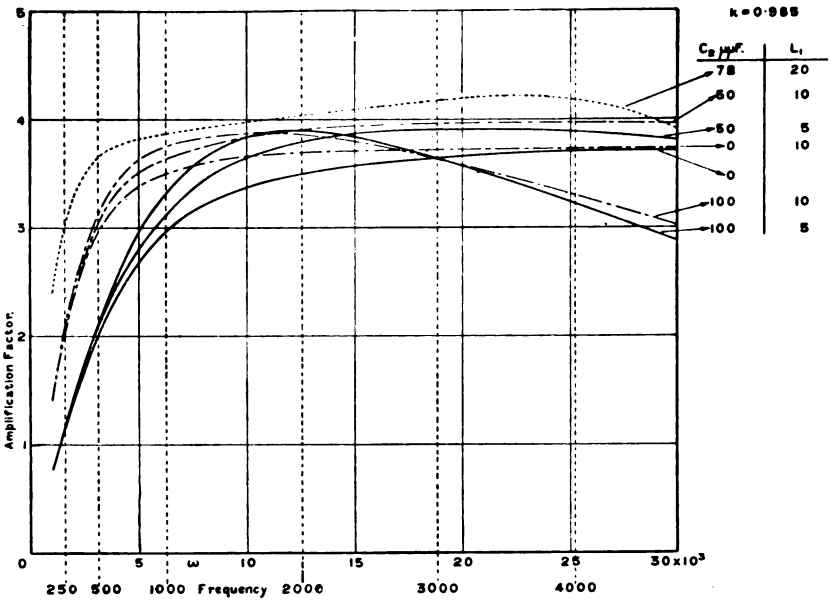

FIG. 25.

of the two windings). From the point of view of ratio, secondary and mutual capacity produce effects which may be interpreted in terms of each other by the relation

$$\sigma_{(C_m)}=\sigma_{(C_2)}\left(1\pm\frac{1}{\sigma_0}\right)^2$$

where $\sigma_{(C_m)}$ is the value of σ corresponding to a mutual capacity C_m and $\sigma_{(C_2)}$ is the value corresponding to a secondary capacity C_2: it is not correct in this case to consider mutual capacity as replaceable by an equivalent secondary capacity.

At frequencies below that at which $L_2C_2\omega^2=1$, the effective primary reactance and resistance are increased by added capacity, and the primary voltage factor thereby improved. Below this limit of frequency, the variation of ratio due to imperfect coupling between primary and secondary is small. The effect of capacity

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on amplification below this region of frequency is therefore always an increase.

At frequencies between that at which $L_2C_2\omega^2=1$ and $L_2C_2\omega^2(1-k^2)=1$ the effects are complicated, and involve all the constants of both windings of the transformer. For all frequencies above that corresponding to $L_2C_2\omega^2=1$ the primary voltage factor steadily falls. A compensation is, however, afforded by the simultaneous rise which occurs in the ratio. The product, giving the amplification factor, may rise or fall or it may keep constant over a considerable part of the region between that where $L_2C_2\omega^2=1$ and $L_2C_2\omega^2(1-k^2)=1$. The amplification factor may exhibit violent fluctuations in the neighbourhood of the point at which $L_2C_2\omega^2(1-k^2)=1$, but above this point it inevitably falls very rapidly and cannot rise again. It is probably desirable to keep this point at a higher frequency than 6 000 cycles per second.

(9) An amplification curve which droops at high frequencies due to the effect of excessive secondary capacity can be improved theoretically by slightly reducing the coupling coefficient. It is not easy to do this in a finished transformer without at the same time reducing the primary inductance, but in the case where an external secondary capacity was used it would be possible to include in the secondary circuit a small external self-inductance. Any reduction in k will cause a corresponding reduction in the ratio at low frequencies. This reduction will in general, however, never be greater than a few per cent.

(10) By a judicious adjustment of k and C_2 to suit each other and the transformer, the amplification ratio can always be improved over that existing in the absence of C_2 or when k=unity. This statement may appear contradictory to the usually accepted ideas on intervalve transformers, but escape from this conclusion appears impossible in the light of the theory developed here. This indicates that a certain amount of secondary capacity is advantageous throughout the whole useful range of frequencies. The desirable value falls within that conveniently obtainable in practice unless the ratio of the transformer is exceptionally high. The higher the ratio or the greater the primary self inductance the smaller becomes the desirable value of capacity. Under these conditions also the coupling coefficient should approach unity more closely. A secondary capacity round about the value $\frac{1\,000}{\sigma_0^2}$ in $\mu\mu$F will in general give good results and should bring the resonant frequency to the region between 1 200 and 2 000 cycles per second.

No experiments have been made on the effect of the steady magnetisation of the transformer core as a result of the steady anode current. So long as this magnetisation is not up to the knee of the $\mathcal{HB}$ curve the effect of the superposed steady magnetisation will be to increase the effective alternating

TABLE V.

AMPLIFICATION FACTOR.

ω	$L_1=20$, $\sigma_0=4$, $S_1=5\times10^5$.								
	$C_2=0\mu\mu$F.		$C_2=25\mu\mu$F.	$C_2=30\mu\mu$F.	$C_2=50\mu\mu$F.		$C_2=0{\cdot}78\mu\mu$F.	$C_2=100\mu\mu$F.	
	$k=1$	$k=0{\cdot}985$	$k=1$	$k=0{\cdot}985$	$k=0{\cdot}985$	$k=0{\cdot}970$	$k=0{\cdot}985$	$k=1$	$k=0{\cdot}985$
1 000	2·40	2·37	2·41	2·40	2·39	2·35	2·40	2·46	2·43
2 000	3·24	3·20	3·27	3·23	3·25	3·21	3·29	3·32	3·28
3 000	3·53	3·48	3·56	3·53	3·56	3·51	3·63	3·66	3·64
5 000	3·70	3·65	3·74	3·73	3·76	3·74	3·82	3·80	3·64
10 000	3·78	3·73	3·82	3·87	3·93	4·08	3·98	3·68	3·98
15 000	3·80	3·75	3·80	4·00	4·09	4·55	4·09	3·40	4·00
20 000	3·82	3·77	3·78	4·17	4·28	5·25	4·19	3·08	3·91
30 000	3·82	3·77	3·68	4·67	4·70	6·16	3·91	2·50	2·85

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permeability and will be all to the good. This increase may amount to 50 per cent. or 70 per cent. in primary inductance. If, however, the iron is taken up to the bend in its permeability curve or on to the flat portion above the bend, the effects may be serious, both on account of the introduction of harmonics which will result and also on account of greatly reduced effective alternating permeability. The iron will, however, need to be of quite exceptional quality or the anode current be exceptionably large for such a degree of magnetisation to occur. As an example, consider a well annealed sample of Stalloy. To produce a magnetisation of 6 000 gauss will require a value of $\mathscr{H}$ not less than about 2. If we take the total effective length of the core as 8 cms. we shall require about 12 ampère-turns to produce $\mathscr{B}$ =6000. Except perhaps in a loud-speaker stage the product of primary turns and anode current is not likely to reach a value of 12 ampère-turns. If a transformer is required to operate under conditions where such a value of ampère-turns is likely to occur, the transformer should be designed with a large cross section of iron and comparatively few turns on the windings, so as to reduce ampère-turns without sacrificing inductance.

It is, however, not certain what characteristics are desirable in a transformer feeding a loud-speaker stage, since information does not appear to be available concerning the relation between the sound intensity produced and the effective reactance and resistance of loud-speakers under the influence of constant voltage at varying frequencies.

It seems quite certain, however, that intermediate transformers should provide an amplification curve as straight and flat as possible over the longest possible range of audio-frequencies.

Note 2.—The Effect of Magnetic Leakage.

It is not quite certain what is the most accurate theoretical representation of the case, involving the fewest variables, but it becomes very involved if we take more than those shown in Fig. 22, which represents the case for secondary added capacity. It is certain that the properties of the iron must have some effect on the voltage ratio. These cannot be allowed for if the iron losses are represented, as on previous occasions, by a shunt across the primary winding. They have, therefore, been transferred to the secondary winding as the equivalent shunt resistance S_2. This case will also include the case of an external shunt resistance added across the secondary as is sometimes done.

Taking then Fig. 22, we have

$$e_1 = i_1(R_1 + L_1 a) + i_2 M a$$
$$i_2(R_2 + L_2 a + S_2) + i_1 M a - i_3 S_2 = 0$$
$$i_3\left(S_2 + \frac{1}{C_2 a}\right) - i_2 S_2 = 0$$
$$e_2 = i_3 \frac{1}{C_2 a}$$

This will be found to give for the instantaneous ratio the expression

$$\frac{e_2}{e_1} = \frac{S_2 M a}{(R_1S_2 - R_1S_2L_2C_2\omega^2 + R_1R_2 - L_1L_2\omega^2 + M^2\omega^2 - L_1R_2S_2C_2\omega^2) + (S_2L_1 - S_2L_2C_2\omega^2 + R_2L_1 + R_1L_2 + R_1R_2S_2C_2 + S_2M^2C_2\omega^2)a} \qquad (31)$$

From this we find the ratio of the root mean square voltages to be

$$\frac{E_2^2}{E_1^2} = \sigma^2 = \frac{M^2/L_1^2}{\left[1 - \frac{C_2\omega^2(L_1L_2 - M^2)}{L_1} + \frac{R_1R_2C_2}{L_1} + \frac{R_1L_2 + R_2L_1}{S_2L_1}\right]^2 + \left[\frac{R_1}{L_1\omega} - \frac{C_2\omega(R_1L_2 + R_2L_1)}{L_1} + \frac{R_1R_2 - (L_1L_2 - M^2)\omega^2}{S_2L_1\omega}\right]^2} \qquad (32)$$

Let us put $L_1 = L_2/\sigma_0^2$ and $M^2 = k^2L_1L_2 = k^2L_2^2/\sigma_0^2$, where σ_0 = ratio of secondary to primary turns. The equation then assumes the more convenient form

$$\sigma^2 = \frac{k^2\sigma_0^2}{\left[1 - L_2C_2\omega^2(1 - k^2) + \frac{R_1R_2C_2\sigma_0^2}{L_2} + \frac{R_1\sigma_0^2 + R_2}{S_2}\right]^2 + \left[\frac{R_1\sigma_0^2}{L_2\omega} - C_2\omega(R_1\sigma_0^2 + R_2) + \frac{R_1R_2\sigma_0^2 - L_2^2\omega^2(1 - k^2)}{S_2L_2\omega}\right]^2} \qquad (33)$$

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Some preliminary calculations show that we can neglect the terms containing the product R_1R_2. Writing also, $R_1\sigma_0^2+R_2=R_t$ we get the more manageable equation

$$\sigma^2=\frac{k^2\sigma_0^2}{\left[1+\frac{R_t}{S_2}-L_2C_2\omega^2(1-k^2)\right]^2+\left[\frac{R_1\sigma_0^2-L_2C_2\omega^2R_t}{L_2\omega}-\frac{L_2\omega(1-k^2)}{S_2}\right]^2} \quad .. \quad (34)$$

Note 3.—Leakage with Mutual Capacity.

The full working is similar to that in Note 2 ; the accurate resulting expression is :—

$$\sigma^2=\frac{\left[\pm k\sigma_0+L_2C_m\omega^2(1-k^2)\right]^2+\left[R_tC_m\omega\right]^2}{\left[1-L_2C_m\omega^2(1-k^2)+\frac{R_1R_2C_m\sigma_0^2}{L^2}+\frac{R_t}{S_2}\right]^2+\left[\frac{R_1\sigma_0^2-L_2C_m\omega^2R_t}{L_2\omega}-\frac{L_2^2\omega^2(1-k^2)-R_1R_2\sigma_0^2}{S_2L_2\omega}\right]^2} \quad (36)$$

which again reduces to the approximate form

$$\sigma^2=\frac{\left[1\pm k\sigma_0+L_2C_m\omega^2(1-k^2)\right]^2}{\left[1-L_2C_m\omega^2(1-k^2)\right]^2+\frac{1}{L_2^2\omega^2}\left[R_1\sigma_0^2-L_2C_m\omega^2R_t\right]^2} \quad .. \quad .. \quad (37)$$

Note 4.—Transferring Secondary Load to Primary.

In case it is desired to ascertain in any particular case whether this assumption is valid, the accurate expressions for R_{p_1} and X_{p_1} are here given for the case where a secondary shunt S_2 of any value is present and no primary shunt is included :—

$$R_{p_1}=R_1+\frac{M^2\omega^2(R_2+S_2+R_2S_2C_2^2\omega^2)}{(R_2+S_2[1-L_2C_2\omega^2])^2+(R_2S_2C_2+L_2)^2\omega^2}$$

and

$$L_{p_1}=L_1+\frac{M^2\omega^2[S_2C_2^2(1-L_2C_2\omega^2)-L_2]}{(R_2+S_2[1-L_2C_2\omega^2])^2+(R_2S_2C_2+L_2)^2\omega^2}$$

The diameter S'_1 of the equivalent primary circle is found by putting $L_2C_2\omega^2=1$. The expression

$$S'_1=(R_{p_1}-R)_{max_0}\doteqdot\frac{S_2M^2}{L_2^2}(1-R_2S_2C_2^2\omega^2).$$

When the conditions are such that the second term in the bracket is small compared to unity $S'_1\doteqdot S_2\frac{k^2}{\sigma_0^2}$. This condition will in general be satisfied so long as S_2 is not greater than 5 megohms.

First Ambulance Seaplane.

A NEW Fairey seaplane has been built for service in British Guiana between the plantations of a company and the nearest township, and has been equipped with wireless apparatus by Marconi's Wireless Telegraph Company, Ltd. It has been launched for tests at Hamble, near Southampton.

This machine has been specially designed to carry white men who fall ill with fever on the plantations to the nearest place where they can obtain treatment. Hitherto the journey, though little more than 200 miles, has taken seventeen days owing to the many rapids on the river necessitating porterages, and many sick men have not survived it. The seaplane will accomplish the distance in little more than two hours—the biggest reduction so far obtained on any route.

The Marconi installation will enable telegraphic or telephonic communication to be carried on with both ends of the route. A special wireless ground station has been erected on the estates to work in conjunction with the seaplane.

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More about Effective Transmission.

By Hugh N. Ryan (5BV). **[R113**

In this article the author brings up to date, and adds some important facts to, his article on the same subject published last month.

IN my article on "Effective Transmission" in the last issue of E.W. & W.E. there were one or two sentences which probably caused some readers to think that I was suffering from loss of memory. Fortunately, however, this is not the case. The article in question was written eleven months ago, but more important matters crowded it out. It was published last month as a timely warning to those who are about to increase their power in the hope of working America this winter. Unfortunately I was unable to bring it up-to-date before publication, which explains the one or two anachronisms it contains.

During the past year, short wave transmission has developed very considerably, and in this article I can appropriately go straight ahead from the last sentence of the other one, which was "I am wondering if I can span the Atlantic on 4 amps." That was in November, 1923, and the point of the article is well illustrated by the fact that I did *not* succeed in reaching America with this aerial current. I soon began to find that the 4 amps were not "effective." Stations 600 miles away reported signals no stronger than they had been on 1 amp, and not so easy to read. All this work was, of course, on 200 metres, and the set was found to have a very healthy harmonic on 100 metres, which distant stations reported to be as strong as the fundamental.

This was, in fact, the first hint I had of the great carrying powers of the shorter waves, but for the time being I was concerned with 200 metres only, so that harmonic had to go. It was suppressed easily enough, but the aerial current fell from 4 amps to 3.

Here, then, was an adjustment which *apparently* did the wrong thing, and had I not known of the harmonic I should naturally have kept to the adjustment which gave the larger reading on the meter, as, I am afraid, most of us do.

However, since the Danish stations (with whom all these tests were carried out) reported much better signals, I continued to use this smaller aerial current, and was soon rewarded when, on December 2nd, my signals were received in Pittsburg, U.S.A.

Signals were reported to be very weak over there, so I looked for some way of making them stronger. I failed to increase power at all without introducing the harmonic again, but the cause of the trouble was suggested when 2KF politely hinted that a little sharper tuning on my part would make life happier for him (at a distance of two miles !).

Apart from lessening local QRM, it seemed logical that better range might be expected if all the noise was concentrated on one wave instead of being spread out over a band.

The set in use at the time was a direct-coupled Colpitts oscillator, which if not carefully handled is the most broadly-tuned transmitter in existence.

However, the wave was eventually sharpened up by substituting loose- for direct-coupling, and using a tuned plate-supply choke instead of the usual untuned one.

The aerial current with this arrangement was only 2·5 amps, but as soon as I started using it the signals were reported as very strong in Springfield, U.S.A., and also in Northern Africa.

I am afraid that this article has, so far, dealt only with my own work, but I have quoted it to show how a rather carelessly adjusted transmitter can be more or less useless with 4 amps in the aerial, and yet, with careful adjustment and only 2·5 amps, be one of the longest range transmitters in the country. Therefore, "don't worship the amp."

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All the foregoing, though actually written in reference to 200-metre work, applies with equal force on 100 metres and thereabouts, but in addition to this there are a few other little difficulties to be met on the shorter waves.

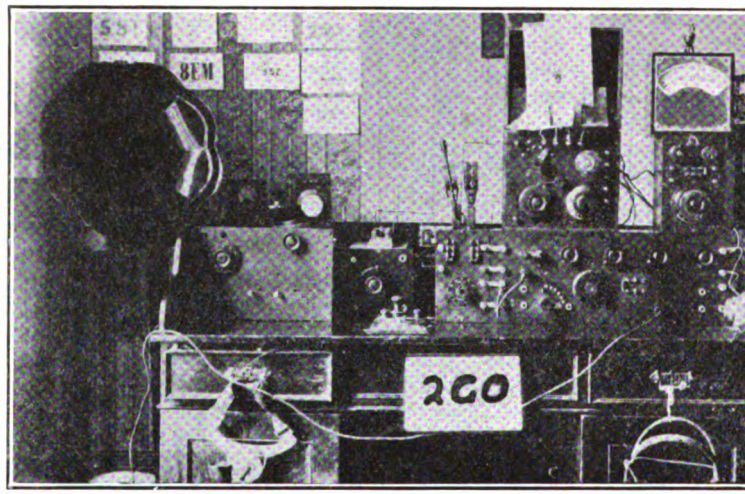
There are, at present, probably a number of experimenters who are transmitting on the 115-130 metre band for the first time, and at first they may be disappointed with the small aerial currents they obtain. Most of us were last year—until the reports started to come in. In the average amateur aerial ·5 amp on 115 metres will give as great a range as four or five amps on 200 metres.

But the chief source of trouble on these waves is the fact that the aerial ammeter hardly ever shows the true current in the aerial. Most stations still use hot-wire ammeters, usually of the ex-Army type, for financial reasons. These meters usually have a metal back through which the terminals pass, and from which they are insulated by mica washers. There is, therefore, a large capacity shunted across the meter, and the higher the frequency the more current goes through this capacity city and the less goes through the hot wire.

Another common trouble is that many people use a low-reading ammeter with a shunt across it, and re-calibrate it. The closed circuit formed by the hot wire and its shunt is often within the field of one of the oscillating coils, when, of course, it has a considerable current induced in it, giving the appearance of a large aerial current. One of the Danish stations was badly "had" in this way last year. I recommend the point to those who think they obtain efficiencies of over 100 per cent.!

Lastly, keep the aerial and counterpoise leads clear of everything, and of each other. I know quite well the smug and complacent feeling that results from seeing the needle of the biggest meter you've got hit the other side of the case, but, believe me, an even more pleasant feeling is obtained when you get a long-distant report, and *then*, the less the current was at the time, the happier the feeling!

I will conclude with one more experience at my own station, this time on the shorter waves. Throughout last year's Transatlantic season I used between 1·5 and 1·8 amps on the short wave. When the year had advanced so far that work with America had practically ceased, I dismantled most of the transmitter for various repairs. At the same time, my aerial came down.



A view of the transmitting and receiving apparatus of amateur British station 2GO, operated by Mr. L. Bland Flagg, 61, Burlington Road, Bayswater, London, W2.

I rigged up a small transmitter for local work, putting under half an amp into a very low temporary aerial (30 ft. high one end and 15 ft. the other).

The signals from this were received *very strongly* in Kentucky, U.S.A., as late in the year as June 2nd, some time after the high power set on the big aerial had ceased to be received in America!

The half amp in a low aerial was thus much more "effective" than 1·5 amps in one 80 feet high. The only difference was that the high-power set used A.C. C.W. and the low-power one pure D.C., which does not seem likely to account for it.

I cannot explain it, so I leave it at that, "stalled" on my own pet subject!

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How to Use up Old Gramophone Records.

By Harry A. Gaydon, A.M.I.A.E., A.F.Aer.Inst. **[R380**

It is now generally known that the material used in the manufacture of most gramophone records has excellent insulating properties, and can be effectively, used for many purposes for wireless apparatus. [*Not* in H.F. circuits.—Ed. E.W. & W.E.] In their normal state records are somewhat brittle, and the material does not readily lend itself to manipulation, although it can be cut with a saw, filed, and even drilled when carefully done, and finished by means of emery cloth. If, however, a record be subjected to the right amount of heat it at once becomes easily workable, and can be cut with scissors and moulded into various shapes with the greatest of ease. On cooling it again becomes hard and will retain whatever shape it happens to be in, indefinitely. It will be as well to mention, however, that all records may not be suitable for this purpose. For instance, "Columbia" and "Regal" are built up as it were, a coarse material being used as a base, and a much finer material covering both sides on which the sound waves themselves are imprinted. Practically all other records, however, are uniform throughout and well suited for the purpose.

One way of heating the material is to place the record in a shallow pan of boiling water for a few seconds and it will then be found that it becomes plastic, almost of the consistency of dough. Under this condition it is easy to cut into any shape by means of a pair of scissors or a penknife (and it is well to warm the scissors or knife first to avoid local cooling) and can be moulded with the fingers as desired. Another method is to carefully heat it in front of a fire, taking care that the heat is uniformly applied. Still another way is by means of a hot metal plate which can be heated over a gas ring to the desired temperature, which will be readily found by experiment. Care must be taken to avoid overheating, otherwise the material itself may catch alight. After cutting to shape, it can be laid on a flat surface such as a piece of plate glass, to cool.

Holes can be cut with a small knife or punch whilst in the plastic condition, and if extra thin material is required it can be rolled down on a hot plate to the desired thickness by means of a length of metal tube, or even a rolling pin. Tubes may also be made by first cutting a rectangular piece to the required dimensions, and rolling round a rod: if necessary a join may be made along the length where the two ends meet by means of a heated metal rod, after the manner of a soldering iron. This however, will require a little patience. Other shapes of tubes may also be made by the same method, such as square, rectangular, etc.

It will be readily seen that many small useful articles can be made, such as small terminal boards, detector blocks, control knobs, insulating washers, lead-in tubes, bobbins, aerial insulators, it being quite easy to mould a shell insulator by first cutting a disc of the desired size, and shaping by means of the forefinger and thumb of either hand, holes being pierced in the required position to accommodate the wire. It can be also used for filling up unwanted holes in ebonite.

In cases where an internal thread is required, it should not be difficult to mould the substance round a screw of the size chosen, and screwing same out when cold, the knurled edge can be readily formed with the blade of a knife when plastic, or filed when cold. After cooling, the articles may be finished by means of a fine file and emery cloth, a good sound job resulting.

It is not suggested that the articles will compare favourably in appearance with those now purchasable for quite small sums, but to those who take a pride in making all their own apparatus as far as possible, as undoubtedly many do, the above should prove of considerable interest and utility.

The most serious disadvantage, however, is a comparatively high power factor (compared with ebonite). But there are many parts and accessories (especially in L.F. circuits) where this is not of importance.

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Some Measurements on a Broadcast Receiver.

By G. W. Sutton, B.Sc. [R220—240

Lecturer in Electrical Measurements, C. & G.(Eng.) College.

In this article the author describes some measurements of received voltage, amplication, etc., on a broadcast receiver.

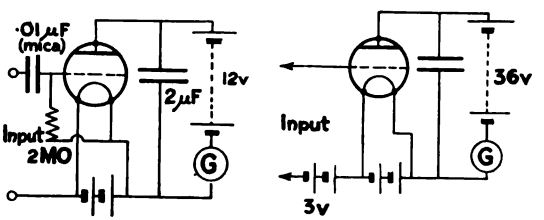
THE following simple measurements of received voltage, amplification, etc., on a broadcast receiver were carried out largely for the purpose of ascertaining the usefulness and limitations of the rectifying valve voltmeter under "amateur" conditions. It was also hoped to gather a little useful information as to the magnitude of the voltages and power employed when operating a small loud-speaker. Owing to limitation of time the results have not been checked and many interesting points have only been partially investigated.

Although facilities were available for carrying out the work under the best conditions as regards apparatus and power supply, they were actually conducted, for the purpose mentioned above, in a small private workroom where the only source of electrical energy consists of 2-volt accumulators (of not too large a capacity) and a limited number of H.T. units.

The most convenient starting point for the amateur about to undertake voltage and current measurements is a thermo-ammeter. The heater and thermo-junction are easy to construct, and, when used in conjunction with a 10s. Weston relay galvanometer, provide a suitable laboratory standard. This may be calibrated on D.C. (by direct comparison with a reliable moving coil voltmeter or ammeter) and may then be used on A.C. of almost any frequency.

Following a suggestion of Prof. Mallett, the author made use of a Weston relay in constructing his valve voltmeters and found it invaluable for the purpose. Owing to its high sensitivity and critical damping it is possible to read rapidly fluctuating voltages, and no difficulty is experienced in levelling or from mechanical vibration. A D.E.R. valve was used and gave very consistent results provided the accumulator was of sufficient capacity to maintain a steady output. A well-charged 20 amp-hour cell in good condition was found suitable.

In the valve voltmeter an A.C. voltage is measured by applying it between grid and filament, employing either cumulative grid rectification (G.R.) or anode rectification (A.R.), and noting the consequent change in mean anode current on a D.C. moving coil milli- or micro-ammeter.[1] The circuits



Grid Fig. 1. *Anode.*

employed in the two types are illustrated in Fig. 1. It is essential in many radio measurements that a voltmeter should take negligible current from the circuit to which it is applied. Some measurements of the voltage-ratio of an intervalve transformer given below illustrate this point. Such current may be due to the inter-electrode capacity of the valve, to grid-filament conduction or, in the case of the grid-rectification instrument, to direct leakage through the grid-condenser and leak. The last may be eliminated by use of a good mica condenser. The second is inherent in the G.R. method and forms one of its drawbacks, but may be eliminated from the A.R. by use of suitable anode battery and grid bias; while the first is avoided by use of the large shunting condenser shown in the anode circuit in each case in Fig. 1. These

[1] See E. B. Moullin. "A Direct Reading Thermionic Voltmeter." *I.E.E.*, Vol. 61, p. 295.

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points are important and neglect of suitable precautions may lead to very erroneous results.

The instruments must, of course, be calibrated on A.C. In the writer's case this was obtained from a valve oscillator arranged as in Fig. 2. (If 50~ A.C. is available from the lighting mains this difficulty may be avoided.) The calibration circuit is also shown in Fig. 2. A P.O. box was employed as potential divider, it being considered sufficiently non-inductive at the frequency used, which was approximately 100~.

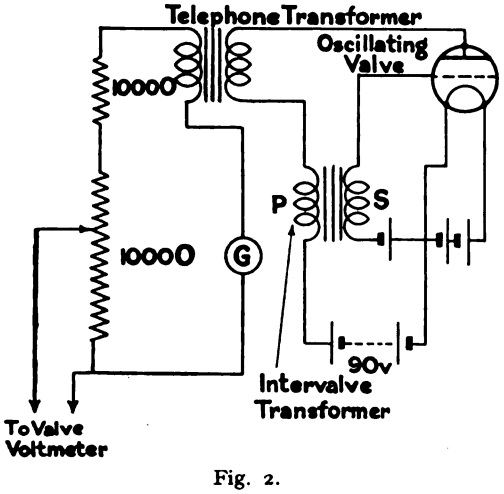

Fig. 2.

The circumstances of the experiment dictate which of the two types of instrument is more suitable for a particular measurement. The G.R. type may introduce an undesirably large amount of damping into a circuit; but on the other hand will read quite small voltages (down to ·02 volt with above arrangement), and is unaffected by D.C. voltages across its terminals. It may be used to measure the voltage on one of two condensers in series (this is not possible with the A.R. type, of course), and so may be employed with a condenser shunt, as shown in Fig. 3. The A.R. type may be adjusted to avoid the introduction of any appreciable damping (up to 2·5 volts in the above case), but is affected by D.C. voltage and must have a closed circuit across its terminals.

It may be mentioned that the galvanometer (only one was available and switching arrangements were adopted so that it might be used in either type of voltmeter circuit) was fitted with a mirror, a spot of light from a 2-volt lamp focused by a 4 in. lantern condenser lens, being reflected on to a 2 ft. scale. There is no reason why a pointer should not be fitted, as suggested by Mr. Sayce in E.W. & W.E., September, 1924. There would, of course, be some sacrifice of sensitivity but a gain in convenience.

One of the most important parts of this experiment was the calibration and checking of the voltmeters. It was found that, so long as the anode, and in the case of the A.R. type, the grid, voltages were fairly closely repeated, and the original zero readings were reproduced by adjustment of the filament current, successive calibration curves coincided as closely as could be read on a graph of foolscap size. Taking all factors into account, it appeared that the instrument could be relied upon to within 1 per cent.

The calibration curves are reproduced in Fig. 4. Zero reading in the case of A.R. was adjusted to 6·0 divisions by means of the filament rheostat whenever a measurement was made, while in the case of G.R., since a *reduction* of mean anode current takes place, a zero of 60.0 was used. These curves illustrate in a qualitative way the conditions under which it is more efficient, from the point of view of signal strength, to employ G.R. or A.R. It must be remembered, however, that the voltages and grid-condenser used are exceptional.

The set upon which the experiments were conducted is a crystal detector and 3-valve resistance-coupled amplifier, which has been giving very satisfactory service for some months in operating a home-made loud-speaker at a distance of some five miles from 2LO on an aerial of moderate efficiency.

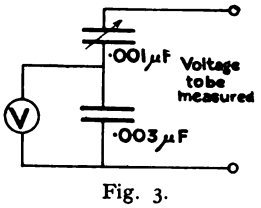

Fig. 3.

The loud-speaker consists of two 60-ohm Brown reed-type earpieces with paper cones attached to the reeds and suspended from the ceiling. Using the three valves the intensity of sound is unnecessarily great, speech being audible all over the house, though distortion is scarcely noticeable. In fact, reproduction compares very favourably with any that the writer or his friends have heard. Two valves are normally sufficient for "comfortable" audibility.

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Like Mr. Colebrook,[2] and for the same reason, the writer adopted 47 S.W.G. single silk Eureka wire for anode resistances some time ago. It seems unfortunate that an even smaller size is not manufactured, since Eureka is mechanically stronger than copper and would give no trouble in winding; 47 gauge is of more than sufficient carrying capacity for the current it is called upon to carry in these cases. Only 40 000 ohm units were in use when these measurements were made, but another 40 000 ohm bobbin has now been added to each, with consequent increase in amplification.

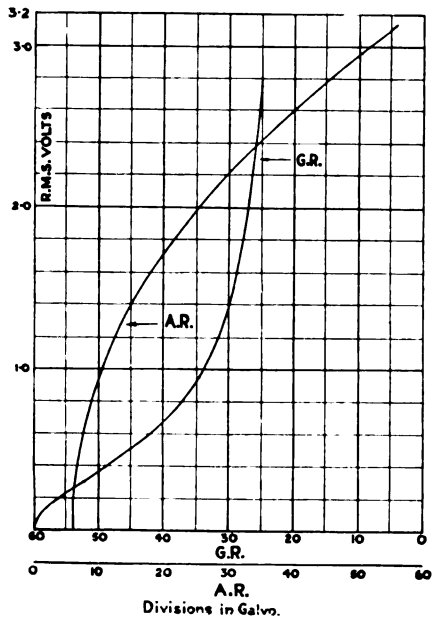

Fig. 4.

The arrangement of the set was largely dictated by the fact that the writer already possessed 2 Wecovalves and a M.O. D.E.R. which he wished to employ. In addition it was considered financially desirable to work on not more than 90 volts or so (three 36-volt units give from 90 to 96 volts for the major portion of their useful lives), if distortionless results could be achieved on that. Thus allowing 30-40 volts drop in the anode resistances of the Wecovalves there remains 50-60 on the plate, which is a suitable value for these small valves. The whole 90 would be available for the D.E.R. since its anode circuit only contains the telephone transformer. It was hoped that this would be sufficient to enable a suitable negative grid bias to be used, so preventing grid current from flowing during any part of a cycle, while working on the straight part of the characteristic. It has since been ascertained that considerable grid current must flow when 3 valves are used, the reason for the comparative freedom from distortion being, doubtless, that the flow produces little effect on the total charge in the 0·1μF coupling condenser, whereas with transformer coupling it would be sufficient practically to short-circuit the secondary.

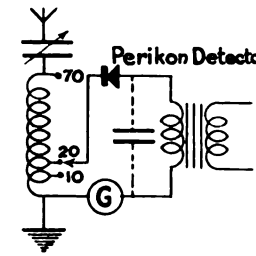

Fig. 5.

A few measurements were first carried out by means of the A.R. voltmeter on the voltage induced in the A.T.I. by 2LO's carrier wave. A 70-turn solenoid, tapped every 10 turns, was employed as shown in Fig. 5. Experiments had previously been carried out along the lines suggested by Mr. Colebrook,[3] and it was found that the maximum value of mean rectified current, 30·3μA, was obtained on the 40th turn, whereas with the crystal circuit connected between turns 70 and 0 only 25·8μA were obtained.

TABLE I.

Radio Frequency.	Voltages. (All in R.M.S. Volts.)			
A.T.I. Tapping.	(*a*)	(*b*)	(*c*)	(*d*)
70	1·50	·40	·71	·97
40	·90	·27	·48	·70
30	·68			·55
20	·44			·35
10	·21			·15

(*a*) Detector disconnected.
(*b*) ,, connected to 70th turn.
(*c*) ,, ,, ,, 40th ,,
(*d*) Valve detector (grid rectification) in place of crystal.

[2] E.W. & W.E., September, 1924.

[3] *Wireless World*, April 30th, 1924.

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The most interesting of these figures is the ·40 volts column (B) and ·48 volts column (C), which show a 20 per cent. increase in voltage on the detector circuit by placing it across the 40 instead of the whole 70 turns. A 20 per cent. increase of mean rectified current was brought about at the same time. A drop of 0·06 volts across the primary of the intervalve transformer was observed even when there was no modulation of the carrier wave. This was eliminated by shunting a ·0002μF condenser across the winding. This ·06 volts thus represents an appreciable and avoidable loss.

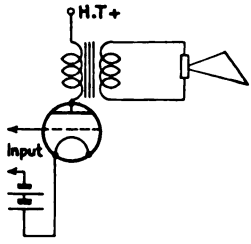

Fig. 6.

Audio-Frequency Voltages.

Attention was now directed to audio-frequency voltages. The writer was surprised to find that the maximum voltage produced during half-an-hour's concert was only 0·1 volt (approx.) across the primary of the intervalve transformer, although the H.F. voltage under rectification was 0·48. Thus the modulation would appear not to exceed 20 per cent.

It was desired to ascertain fairly accurately what the maximum grid swing was on each valve with the loudest received signal,

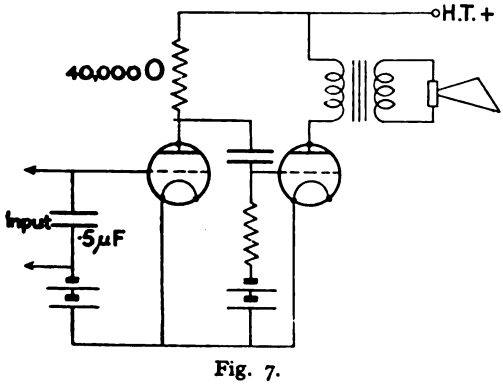

Fig. 7.

and with this purpose the voltage across the secondary of the telephone transformer used with the loud-speaker was observed for some time. With all three valves in circuit this was 2·1 volts. (This could be observed more accurately on the A.R. voltmeter than could the 0·1 volt mentioned above even on the G.R. voltmeter.) Unfortunately the rapid fluctuations made observation very difficult on the normal 2LO transmission.

A 700-cycle oscillator was therefore set up and connected to the input of the amplifier. This led to some extraordinary results which were found to be due to the oscillation of the set at some radio-frequency, possibly due to the fact that the anode resistances were by no means non-inductive. This trouble was eliminated by connecting a large (·5μF) condenser across the input terminals, and so earthing the first grid so far as H.F. voltages were concerned.

The maximum signal voltage at the output end of the set being known it was necessary to measure the voltage ratios at each succeeding stage of amplification. That on the third valve was attempted first, the circuit being as shown in Fig. 6 and the results in Table II.

TABLE II.

Input Volts.	Volts on Secondary of Transformer.	Ratio
·24$_5$	·11$_5$	× ·47
·58$_5$	·24	× ·41
·82	·37	× ·45
1·37	·60	× ·44
		mean × ·44

Then the amplification due to the second Wecovalve was measured, the circuit being as shown in Fig. 7. From the static characteristics of this valve μ appeared to be 5·6 and R_a 21 000 ohms. Thus, using an anode resistance of 40 000 ohms, the maximum step-up would be ×3·7. Table III. gives the results of this test.

TABLE III.

Input Volts.	Volts on Grid of D.E.R.	Ratio.
·12$_0$	·43$_5$	× 3·5
·21$_5$	·74	× 3·4
·32$_5$	1·09	× 3·4
·41$_5$	1·36	× 3·5

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As a check on Table II. and Table III. the results in Table IV. were obtained.

Connections as in Table VI.

TABLE IV.

Input Volts.	Volts on Secondary of Telephone Transformer.	Ratio.
·12$_5$	·19	× 1·52
·25	·38	× 1·52
·37	·55	× 1·49
·60	·92	× 1·53

The agreement is very close :—

·44 (Table II.) × 3·45 (Table III.) giving 1·52.

The step-up ratio of the intervalve transformer was now measured, the G.R. voltmeter being employed. The results obtained are given in Table V.

TABLE V.

Primary Volts.	Secondary Volts. Grid of Voltmeter to " O."	Grid of Voltmeter to " I."	Ratio.
·08	·29	·35	× 3·6 × 4·4
·12	·40	·48	× 3·3 × 4·0
·18$_5$	·58	·66	× 3·1 × 3·6
·23	·69	·80	× 3·0 × 3·5
·37	·89	1·02	× 2·4 × 2·8

This test was repeated at several different frequencies with much the same results. Two interesting facts emerge from this. Firstly it illustrates the marked effect of damping due to grid current taken by the voltmeter. This is negligibly small at ·3 volts but rapidly increases. Secondly it shows that under such conditions the direction in which the transformer secondary is connected in circuit is important. When the test was repeated, using the A.R. voltmeter, neither of these effects was noticeable, a typical reading being :—

P 0·8 volts. S (either way) 3·37; ratio 4·2.

Finally, the loud-speaker consumption was noted. The loudest signal so far recorded, and then only for an instant, produced a drop of 2·6 volts across the phones. When this voltage was reproduced by the 700-cycle oscillator the current flowing in the phones was found to be 1·7mA. Thus the maximum consumption was 4·5 milliamp volts. It is obviously not justifiable to consider this to be the power input in milli-watts and time did not permit the measure ment of the P.F. of the circuit. It is sufficient to give an idea of the approximate consumption however.

All the voltages so far recorded are in R.M.S. or effective values. In Fig. 8 these have been converted where necessary into amplitude of grid swing on the assumption of sinusoidal A.C. wave. The voltage on " d " has been taken as 2·1 (corresponding to a loud signal), and, employing the ratios as determined above, that on P. is found to be 0·09—in close agreement with the directly observed value of 0.1.

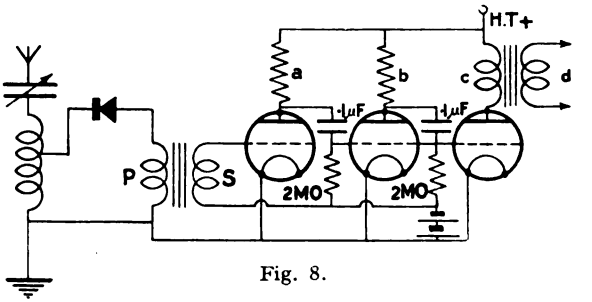

Fig. 8.

	P.	S.	a	b	c	d
R.M.S. volts.	·09	·39	1·36	4·8	25	2·1
Grid Swing.		1·1	3·8	13·5		

S/P = 4·2 : 1. d/c = 1 : 12.

From these figures it is seen that the grid swing is only 3·8 volts on the second Weco-valve. Thus, these two valves could be run on a V_a of only 35 volts and V_g – 1·0 without causing appreciable grid current to flow or moving off a fairly straight portion of the characteristic. One peculiar point noticed with these little valves is that no grid current flows till about 1·6 volts positive is reached on the grid. Operating thus a mean anode current of 0·4 milliamps would be used, and if R_a were raised to 150 000 ohms only 96 volts total H.T. would be required.

The difficulty is the third valve. One allowing for a grid excursion of about 15 volts without moving off the straight part of the characteristic or producing a grid current, when operating with a V_a of 95 volts, is called for. The D.E.R. would fulfil this if provided with 150 volts V_a.

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The Perfect Set.

Part II: The One-Valve Set. [R343

Below will be found the second of a series of articles dealing very thoroughly with a subject of great importance both to the advanced experimenter and the ordinary listener.

IN considering the design of a one-valve set, we are confronted by a problem singularly different from that of the crystal set dealt with last month. In that case we were dependent entirely upon the energy supplied from the transmitter *via* the aerial, and our main effort was to conserve it. The avoidance of losses became by far the most important point.

In the valve set, on the other hand, we are utilising a local source of energy—the high tension battery—and the problem is rather to ensure that the incoming signals release this energy to the maximum extent consistent with an exact control. Further, the use of reaction affords a method of compensating for many losses, so that the design of the aerial circuit for low resistance is not of such importance.

This last point, be it noted, is one about which there has been much discussion: is it or is it not true that reaction can make up for inefficient circuits? Recent investigations all tend towards the answer "Yes," as regards certain kinds of inefficiency. Reaction will compensate for high resistance. The oft-mentioned "negative resistance" effect is a real one, so that an aerial circuit of 50 ohms with a reaction effect of —30 ohms behaves, as regards strength and selectivity, just like an aerial of 20 ohms. But reaction apparently will not compensate for bad design in the valve circuits themselves, the use of unsuitable voltages, bad telephones, etc.

In the long run, then, successful design in the one-valve set depends on having the valve circuits suited to the valve. Just as a reminder, Fig. 1 shows the standard circuit.

The Aerial Circuit.

In this part of the set our efforts must lie in the direction of getting the biggest possible voltage between the valve grid and filament. In the case of a crystal, as shown in our last issue, it is correct to design the circuit on the principle of equal losses in aerial and crystal: for a high impedance crystal a high-voltage circuit and vice versa. The same applies here. But the input circuit of a valve (at broadcast wave-lengths) has a very high impedance compared with a crystal: it may be, according to the type of valve and the circuit arrangements, 10 000 ohms to perhaps 200 000. Hence the aerial circuit should be designed to have

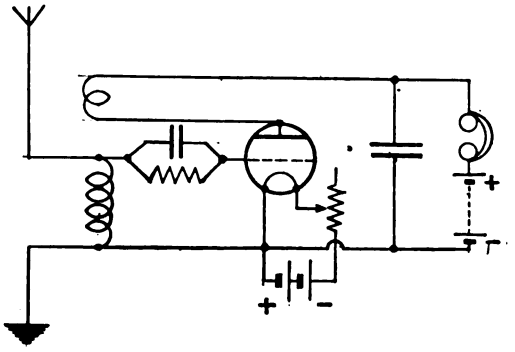

Fig. 1.

as large a voltage as possible across its inductance; and this means a large inductance. To enable a large inductance to be used, while still tuning down to the neighbourhood of 300 metres, means putting an aerial condenser in series with it. So that our typical aerial circuit uses a tuning condenser and fixed coil.

The same idea as last month of transforming up or down to suit the load, may be embodied. It will be remembered that in the crystal circuit this led to a design like Fig. 2A, in which the crystal was tapped off part of the coil, to prevent excessive damping. With the high resistance valve circuit, however, we work in the opposite way: we wish to transform *up*, so we arrange the circuit as in Fig. 2B. Since in this case the high voltage is obtained by

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transformer effect, it is not so necessary that the voltage between A and B should be large, hence we can include only the actual inductance required to time, and the condenser may be omitted. In actual practice, however, this circuit is not a favourite, for it does not lend itself so well to getting long waves as well as short, since one cannot use the favourite plug-in coils. But if one wishes only to cover the "broadcast band" of 300—500 metres it is hard to beat.

The Valve Circuits.

In considering the valve circuits, we must study detector action a little, and we are presuming throughout that the standard method of grid rectification will be used.

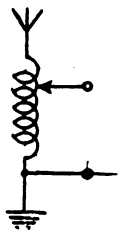

Fig. 2A.

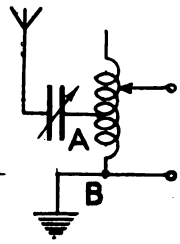

Fig. 2B.

As we all know, this depends on having the grid kept, by the grid-leak, at such a steady potential that a very slight grid current flows from filament *via* leak to grid and thence through the valve back to filament. When the incoming signals impress an alternating voltage on the grid, a larger current flows every time the grid becomes more positive, but no current flows as it becomes more negative each cycle. Hence there is an accumulation of charge on the grid and its condenser, which can only leak away slowly through the grid-leak. Let us look into the quantities.

Obviously we are here dealing with a characteristic of the valve which is not often enough given to us by the valve-maker, and which is, unfortunately, not very easy to measure: the relation between grid volts and grid current.

Valves naturally vary greatly on this point, but the sort of relationship likely is shown in Fig. 3. The grid current is *nil* below about —0·5 volt, and then rises, slowly at first and then rather rapidly. Now on studying this particular curve, we can see that the best steady grid voltage is obviously about +0·2V, where the curve is sharpest (the point marked A). The grid is to be maintained at this voltage by the leak, and we must now find how to arrange the leak to do this. Consider Fig. 4.

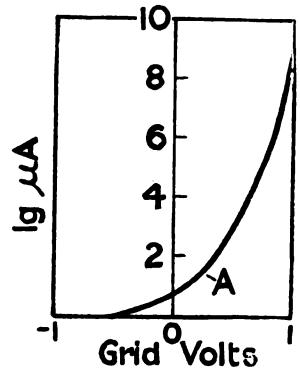

Fig. 3.

The point 0 volts corresponds to the negative side of the filament, which we take as our zero. It we take a 2MO grid-leak, connected to the negative side, we can say that the grid volts and current must correspond to some point on the line OB. For the leak follows Ohm's Law: for every one volt on it there must be

$$\frac{1 \text{ volt}}{2 \text{ Megohms}} = \tfrac{1}{2}\mu\text{A},$$

which is true for the line OB. If we were using a 1MO leak, the line OC would represent it, for in this case 1 volt must give 1μA.

Suppose we connect to the positive side of the filament, say at 4 volts positive. Then the grid current and voltage must be represented by lines such as 4D, 4E in Fig. 4, 4D being for a 2MO leak, and 4E for 1MO.

But we know that the grid volts and current are already represented by the curve of Fig. 3. If now we draw both

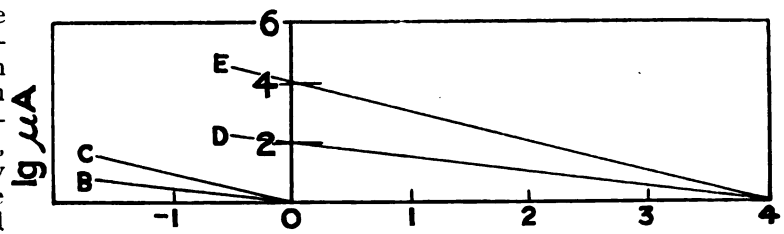

Fig. 4.

Figs. 3 and 4 together, as in Fig. 5, we see that (taking the line 4E as an example) there is just one way in which the grid volts and current can fulfil the conditions of Fig. 3 and also of Fig. 4: the grid will set itself at the point represented by F: about 0·6

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volt positive, with a grid current of about 3μA. Now, referring back to Fig. 3, it will be remembered that it was desired to keep the grid steady at the point A. This can

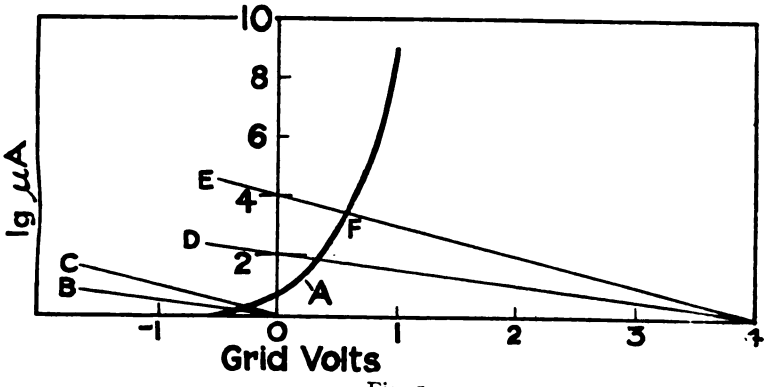

Fig. 5.

obviously be done, as shown in Fig. 6, by a 1MO leak connected to a point at about +1·3 volts (line GH) or a 2MO leak connected at +1·8 volts (line KL) or by other values of leak, provided the leak is connected to the correct voltage. In practice, the best value of leak must be governed by various high frequency considerations, two complicated to be set out here. Generally speaking, a leak of anything between 1 and 3MO will do almost equally well, provided the lower end is connected to a point at the right voltage. What this right voltage is depends entirely on the valve, and in practice the simplest method of finding and keeping it is by using a potentiometer across the filament. For even if we get from the valve makers a curve showing grid current, it must be remembered that a change of anode volts makes quite a difference to the grid current curve. There is, however, one little catch in adjusting grid potential by just listening to signals. Suppose we set the grid a little too negative for best rectification, we are losing signal strength; but we are also decreasing grid currents and we are decreasing the damping effect of the valve on the aerial circuit. The reaction has less loss to work against, we get nearer to oscillation point, and the increase due to this may hide the decrease due to not getting the best rectification. In other words, after each adjustment of grid potential re-adjust the reaction to just off oscillation; then judge the signal strength.

We have now dealt with the size of leak and the connection of the filament end of the grid circuit. There remains the grid condenser. Here again the question of its value is a complicated matter. But, as in the case of the leak, quite a large departure from the theoretical value does not make a large difference in efficiency. Anything between ·000 05 and ·000 2 will serve well with ordinary valves. The use of a variable leak and condenser may sometimes help a little, but it is our firm belief that the use of a potentiometer, connected as in Fig. 7, is much more important, and that if it is adopted variable grid-leaks and condensers are not necessary.

One point, however, is important: the use of a really good grid-condenser, especially from the point of view of high insulation. Since a resistance of 1 to 3MO constitutes the working circuit, the condenser should have an insulation of at least 50MO. Luckily, there are many such available.

The Anode Circuit.

First, perhaps, one should deal with the question of the H.T. battery and its proper voltage. This, luckily, is an easy problem,

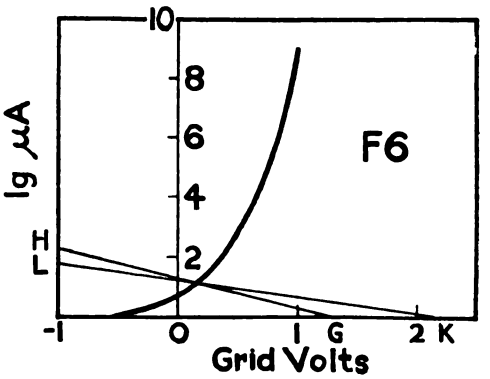

Fig. 6.

if we have available the ordinary characteristic curve of the valve. We know, from previous considerations, that the lower end of the grid-circuit will be held at, say, 2 to 4 volts positive, and that the grid itself will be in

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the neighbourhood of zero—say between — 1 and +1 volts steady potential.

We know also that the invariable effect of signals will be to make the grid more negative. We want this change of grid volts to produce the largest possible change of plate current. Therefore, the anode voltage must be such that the top of the "straight" part is at say +1 or +2 volts—in other words, if the characteristic curves are like those of Fig. 8, the correct voltage would be 60, though if the incoming signals are weak, so that the change of grid-volts is only small, one could use 40 volts.

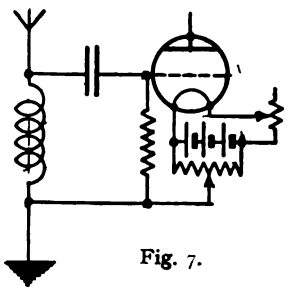

Fig. 7.

This, however, should be the steady voltage on the anode itself. It must not be forgotten that part of the battery voltage is taken up in driving the current through the phones, etc. If for example the steady plate current is 2μA and the phones have a direct current resistance of 4 000 ohms, there will be eight volts lost in them, and the battery should be this amount higher than the required actual anode volts.

Next, as to the various items in the anode circuit. First, their order. This is fairly well standardised by now, but to prevent any misunderstanding one may as well repeat that the reaction coil must come nearest the anode, then the phones, and lastly the battery. This is for the obvious reason that if the battery or phones were put next the anode, their capacity to earth would shunt much of the H.F. current out of the reaction coil.

The necessary size of reaction coil depends on the size of aerial coil, the efficiency of the circuits, and the type of valve. Less is needed if the valve has a high magnification, etc., if the circuits are of small H.F. resistance, or if the aerial coil is large. It will be found a great convenience to use a fairly large coil, so that the amount of action wanted can be got with the coils some way apart; for if it is necessary to bring them close together, one is confronted with the annoying feature that the slightest change of position has a quite large effect on wavelength and necessitates re-tuning. There may also be difficulty owing to the capacity-coupling between the coils, which may or may not assist in producing oscillation. For the same reason, it is wisest to choose a coupling arrangement in which the coils move quite widely apart. In a type sometimes used, in which one coil moves across the other, there are sometimes surprising fluctuations of coupling at certain points; the coupling may change from positive to negative and back again within a few degrees of movement. The one important point is a really delicate adjustment.

The next item in the anode circuit is the telephone with its shunting condenser. The resistance of the phone must be considered. It is, of course, its impedance to alternating current of audio-frequency that matters, and, unfortunately, this is a very variable quantity. However, one will not be far wrong in using the usual "4 000 ohm" phones. These have a low-frequency inductance, as a rule, of about 5 Henries, or thereabouts, but their self-capacity usually causes them to resonate within the audible range (often at about 1 000 cycles), and in this neighbourhood their impedance varies rapidly. The shunting condenser (which should be across the H.T. battery as well)

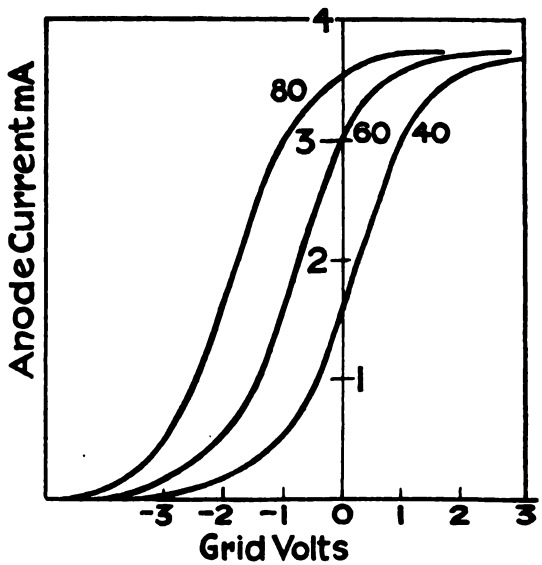

Fig. 8.

has to pass the H.F. component of the anode current. Its value is considered in part of an article elsewhere in this issue ("A Simple Way to Calculate Circuits," p. 69), and reasons are there discussed indicating that its best value is nearer ·000 1 than the usual value of ten times that amount.

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A Neon Lamp Method of Comparing Capacities and High Resistances.

By W. Clarkson, M.Sc., and J. Taylor, B.Sc. **[R220-240**

In the following article, which is a simplified version of their original paper, the authors consider the use of the Neon Lamp for comparing capacities and high resistances and describe some of the methods employed.

I.—General.

READERS will be familar with the glow discharge of the Neon lamp, and with the fact that when a fairly large capacity is placed in parallel with the lamp the discharge becomes regularly intermittent. A circuit for demonstrating this phenomenon of "flashing" is indicated in Fig. 1, in which L is the lamp, E the battery (of about 200 volts), driving the lamp, R, is a resistance of the order of a megohm, and C is the capacity.

Using such a circuit it has been found that the relations between the period of flashing T and the capacity, and between T and the resistance are linear, being expressed by the relation

$$T \propto RC.$$

Figs. (2) and (3) respectively show the relationship between T and R when C is constant and between T and C when R is constant. In obtaining these graphs E was kept constant at approximately 190 volts, C and R were varied as indicated and the times T for one hundred flashes were measured by a stop-watch. As will be seen, the graphs are linear and intersect the C axis at a point not far removed from the origin. These relations hold with C as great as 7·0 microfarads, and were also obtained with E of values ranging from 180-260 volts. We may say then that,

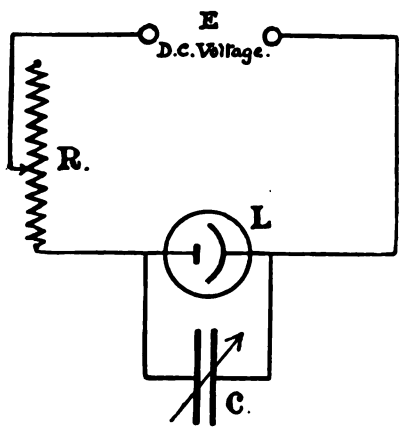

Fig. 1.

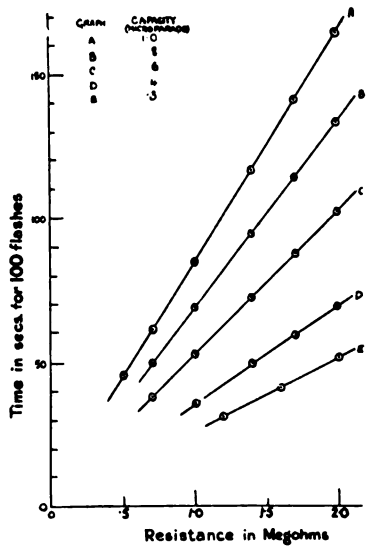

Fig. 2.

the other factors being constant, T is a measure of R in one case and of C in the other. The application of this to the comparison of capacities and high resistances is obvious.

It is not necessary, however, to limit oneself to values of C and R which permit countable flashes. If headphones are included in the circuit of Fig. 1 and C is steadily decreased it will be found that the frequency of the flashes is increased correspondingly, and finally a musical note is heard in the telephones. On further decreasing the capacity the note can be made more and more shrill, until it becomes a faint hiss. This final state indicates a frequency of 20-30 thousand periods per second and even this by no means the limit of obtainable frequencies. Obviously

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timing is impossible in these cases, but by utilising the sensitiveness of the ear to the change in pitch of a note or alternatively by producing "beats" between two frequencies, several delicate methods of comparing resistances and capacities have been developed.

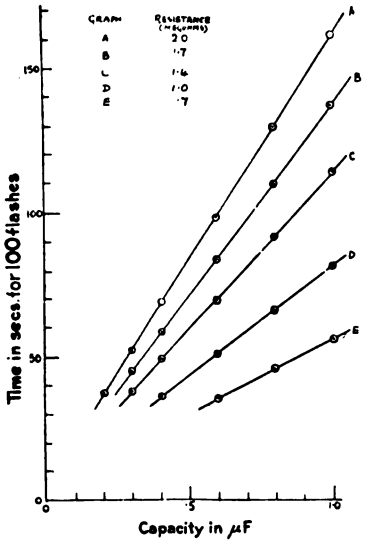

Fig. 3.

The method may be placed in two groups: "Timing" methods, involving the use of countable flashes, and "Note and Beat" methods.

Using such methods, capacities of from 0·000 2 to 7·0 microfarads have been measured, these purely virtual limits being fixed solely by the condensers available. In the case of resistances, however, both experiment and theory show that there is a lower limit to the value of R, below which no "flashing" is possible. Since this limitation can be overcome in a simple manner, as will appear later, it scarcely affects the range of resistances which can be employed.

II.—Apparatus.

Before discussing the details of the various methods advanced, a few remarks about the apparatus are essential. The lamp used in the experiments was an ordinary "Osglim" trade-sign lamp, letter "O" pattern, from which the ballasting resistance (included in the cap) had been removed. Before regular use the lamp was "aged" by being overrun for some time. The high tension battery was composed of small Leclanché cells, voltages greater than 170 volts being necessary. The fluctuations of voltage prevented consistent results from being obtained when the 240 D.C. mains were employed. Whenever possible the action of the battery was steadied by a large condenser being placed across the battery terminals. Since the currents never exceed one or two milliampères, no decrease in voltage due to polarisation occurred, even when the battery was run continuously for long periods. This small current permitted the use of telephones in all circuits without fear of damage.

If possible the lamp should be kept running throughout the experiment, so that the conditions are kept as unvarying as possible. After varying the circuit a short interval should be allowed to elapse before timing is attempted. Time periods greater than 2-3 seconds are not recommended, as it is our experience that they give inconsistent results. Headphones were used in timing, as the sharp clicks in the telephones were easier to time than the corresponding flashes of the lamp.

III.—Comparison of High Resistance.

The apparatus for comparison of high resistances is indicated in Fig. 4, the key

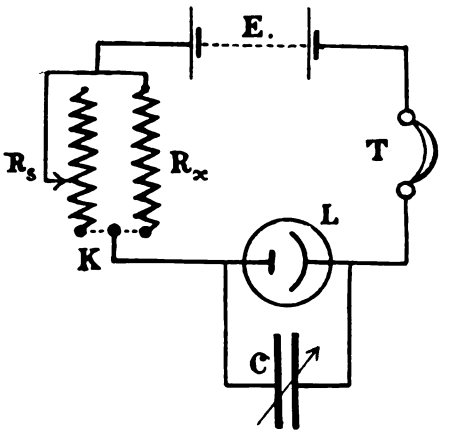

Fig. 4.

K being arranged so that either R_s the known variable resistance or R_x the unknown resistance can be introduced into the circuit at will.

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Both an approximate and an accurate method are given below :—

(A) With R_x in the circuit, E and C are adjusted until the lamp is flashing at a suitable rate, the time T_x for one hundred flashes is found, and the standard R_s is then introduced and adjusted until T_s is of the same order as T_x. If we assume that the T, R graphs pass through the origin, then R_x is given by

$$R_x = \frac{R_s T_x}{T_s}.$$

Though the result is sufficiently accurate for many purposes the procedure must be modified as below if exact results are required.

(B) This method is based on the fact that though the T, R graphs do not pass through the origin, yet they are straight lines. Two values of R_s are taken, R_1 and R_2, giving timings T_1 and T_2 respectively. R_x is then obtained from the relation

$$R_x = \frac{R_2(T_x - T_1) - R_1(T_x - T_2)}{T_2 - T_1}$$

IV.—Comparison of Capacities.

Fig. 5 gives the arrangement for the comparison of capacities, C_x being the unknown capacity, C_s the variable standard, and K a switch by which either C_x or C_s can be placed in parallel with the lamp. The methods employed are similar to those just described, as are also the calculations.

Note Methods.

The circuit given in Fig. 5 is also employed in the note method for the comparison of capacities.

With C_x in the circuit, R_2 and E are adjusted until a clear note is heard in the telephones T. The key is now thrown over rapidly, C_x thus being replaced by C_s, and C_s is varied to reproduce the same note in the headphones as given by C_x. By quick reversals of the key the capacities are rapidly interchanged and each time C_x can be varied until finally on substituting C_s for C_x no change in the pitch is detected. The value of C_s now equals that of C_x, for the frequencies of the two arrangements are identical.

The method has the advantage of simplicity and gives very accurate results if the observer possesses a sensitive ear.

Beat Methods.

Beat methods, though more complex, are less liable to errors of personal observation and permit still more exact correspondence between frequencies to be made. The methods are based on the fact that if both C_x and C_s are such that they produce frequencies giving the same number of beats per second when combined with a standard frequency, they must be equal. Since high-pitched notes are used and very slow beats are produced, small differences in frequencies are easily detected, and thus fine adjustments of C_s are possible.

In practice, a circuit arranged as in Fig. 1 was used to produce the standard frequency, C_x and C_s being arranged as in Fig. 5.

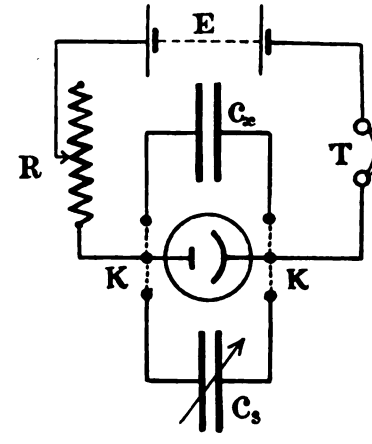

Fig. 5.

In order that beats may be heard the coupling of these circuits must be by telephones and by the battery also if two batteries are not available. This is the arrangement given in Fig. 6. It is best to have C a variable condenser with a value of the same order as C_x, and R_1 and R_2 therefore approximately equal, with a value of about 4 megohms.

With C_x in the circuit, R_2 and E are adjusted to give a high-pitched note and then C altered until slow countable beats are obtained. C_s is now inserted and adjusted to give the same number of beats per second as given by C_x. With this adjustment, C_s is evidently equal to C_x. It is, of course, necessary to see that *both* C_s and C_x are giving frequencies above that given by C,

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or *both* below. When using this arrangement, it is not convenient to adjust the condensers so critically that no beats are obtained, as the forced interaction of the circuits due to their close proximity and to their coupling causes this to occur over a relatively wide range of capacities. This difficulty is overcome, in a great degree, by methods to be given later.

The 240V D.C. supply was utilised in this method with success, though sometimes the voltage varied sufficiently to alter the beats from time to time. When two batteries are obtainable, forced interaction between the circuits is greatly reduced by using suitable coupling and by keeping the circuits some distance apart. It is possible to reduce the "no beat interval" to very small proportions and to obtain slow distinct beats even when using faint hissing notes. Diagrams of the arrangements are not given here, as many efficient methods are possible. Very delicate measurements have been effected by means of some of these.

All the circuits given as suitable for comparing capacities can be used, with appropriate modifications, for the comparison of resistances, though they are not so sensitive to small changes in resistance as to small changes of capacity. The circuits are modified in the following way: Though the circuit giving the standard frequency is unaltered, the second circuit is like that in Fig. 4, instead of that in Fig. 5 as previously. The procedure is analogous to that of the corresponding method for capacities.

Since the value of R below which no "flashing" is possible is generally about 0·4 megohms, resistances less than these cannot be used alone, but must be included in series with another of suitable size. If this latter resistance, easily made by pencilling on ebonite, is also included with R_s, the latter will record R_x directly when adjusted.

In a similar manner, a capacity giving frequencies too great for timing can be placed in parallel with another capacity, the time period being thus reduced to a convenient value.

Intercalibration.

In cases where it is desired to intercalibrate variable condensers and note or beat methods can be used, the two variable condensers should be placed in parallel with, say, C_x as large and C_y as small as possible. The settings of C_x and C_y are recorded and C is adjusted as in previous methods. C_x is now decreased and C_y increased until

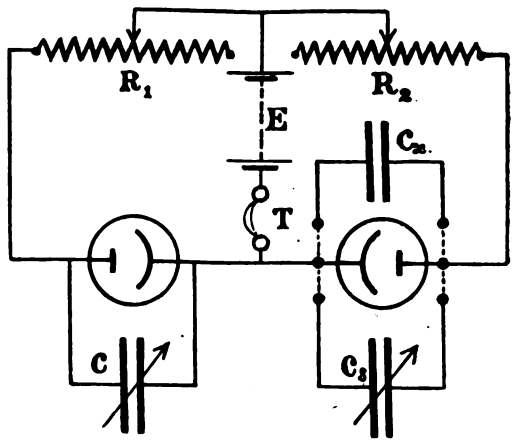

Fig. 6.

the same note is heard or the original beat frequency is obtained, when, of course, the decrease in C_x is equal to the increase in C_y. This progress can be continued until C_x is calibrated in terms of C_y. Their relation can be recorded graphically if a handy record is desired.

If C_x is greater than C_y, it is necessary, after the range of C_y has been covered, to restore C_y to its original value without re-altering C_x, and to reset C so that in time the whole of C_x will be calibrated. The same principle can be applied to the calibration of variable resistances.

(For a more theoretical discussion of the methods, the reader is referred to the original paper in the *Journ. Scien. Inst.*, below.)

REFERENCES.

On the "Flashing" of the Neon Lamp :—

Anson and Pearson.—*Proc. Phys. Soc.*, Vol. 34 (1922), p. 204.

Taylor and Clarkson.—*Jour. Scien. Inst.*, Vol. 1 (1924), p. 173.

On the Circuit Resistance below which "flashes" cannot be obtained :—

Taylor and Clarkson.—*Proc. Phys. Soc.*, Vol. 36, Part 4, p. 269.

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Duplex Telephony.

By P. P. Eckersley, M.I.E.E. **[R460**

Capt. Eckersley needs no recommendation from us. In this article he outlines the problems of Duplex Telephony and describes a few methods of achieving and operating it.

THE Duplex Wireless Telephone possesses certain undeniable advantages. In the usual system of Wireless Telephony a certain formality has to be studied in the exchange of messages; like the waiter who blows down the speaking tube to give his order, and has to change over to receive to find if the *chef* has interpreted "Adam and Eve on a raft, and wreck 'em" as scrambled eggs on toast. It is doubtful whether the waiter finds his job the more arduous on account of this formal interchange of messages, or if he finds the difficulty of not being able to send and receive simultaneously a serious one; but the waiter is an expert on the speaking tube. One has only to listen to the conversations between ground and air on the London-Paris airway communications to realise that with skilled participants the ordinary simplex system lacks nothing in efficiency. Thus the wireless telephone's inferiority to the wired system is not in many cases so pronounced as might at first be feared, and it has even this supreme advantage, that it discourages "chatting." With unskilled participants, however, the system is provedly hopeless.

The wireless telephone, apart from its commercial value in broadcasting, has an aspect of real usefulness inasmuch as it will, and in certain cases does, provide a long-sought-for link in the wired system. It is a common error among *hoi polloi* (the wireless *hoi polloi*, I mean—so numerous a class now that every up-to-date house has its aerial) to suppose that the wireless telephone will oust the wired; but to readers of this more scientific wireless paper I need hardly point out that the future of the wireless telephone for commercial purposes is to supplement, and not to supplant the older system of voice communication. Thus a real need for Duplex is apparent, whether it be to bridge the Atlantic for the ordinary telephone subscriber on the one hand, or to allow business men on ship, in the air or the train to keep in touch with their offices, on the other.

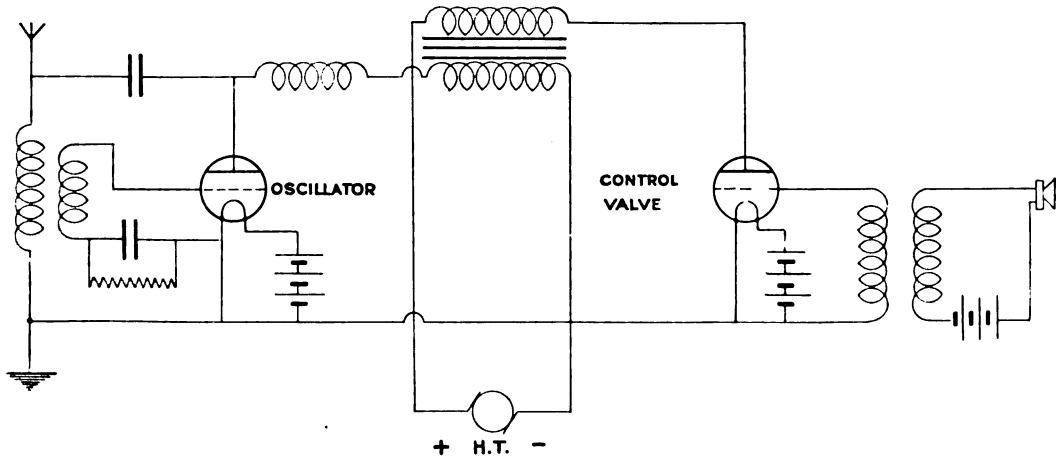

Fig. 1.

The writer may claim to have studied Duplex Telephony in its ground to aeroplane aspect perhaps more deeply than most, but as the problems of the aeroplane contain the lesser problem of ground communication, it might be interesting to go over in part the work done in 1918-19 in co-operation

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with other wireless experimental officers of the R.A.F. If the reader is curious to know details of some painstakingly abortive experiments, he might care to read a paper delivered by the writer before the Institution of Electrical Engineers in 1919.*

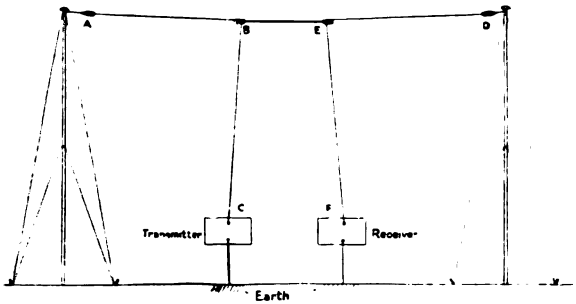

Fig. 2.

The aeroplane problem practically resolved itself into devising a system whereby the operator might be able simultaneously, or as a compromise without moving switches, to send and to receive.

The first experiments aimed at a compromise wherein the voice of the speaker automatically switched on the transmitter. The voice on ceasing automatically restored the receiver to sensitivity, and the reply came to the listener without the need of his moving switches. As a matter of scientific rather than practical interest, the reader may be interested to know that in this method the high tension for the oscillator was supplied entirely by the microphone acting through a powerful voice amplifier, so that only when the operator spoke could the set oscillate. The connections are shown in Fig. 1; really the system is no more than the common choke control arrangement, the steady high tension from the generator being only applied to the control valves, the "voice voltages" not being superimposed upon a steady D.C. potential, but existing alone. It will be immediately apparent that negative swings of the voice variations were ineffective, but theoretically this would seem no bar to intelligibility. It is well known that one can remove a great many components of speech frequency and still retain a recognisable original. In the case of this quiescent aerial system, however, the speech was almost unrecognisable as such, and in spite of ensuring that the valve would oscillate at the least application of H.T. voltage so that was no "threshold," the poor quality, nay! the unrecognisable jumble, remained.

It was Captain Round (it often is!) who pointed out that the jumble was probably due to the phases of the high frequency in one part of the energised periods not being in time with the phases of the next—at least, there was no assurance that such would be the case—and only by a system of double rectification wherein the set was continuously maintained in oscillation, and both halves of the speech wave were employed, would good speech result. I was able to prove the truth of his forecast, but the arrangement was too complicated to permit of consolidation into a robust apparatus, remembering that even were this done the problem would but be half solved. Truly it would be better to change over a switch, and I only have given a passing reference to the experiments to prevent others following a path that leads to a *cul de sac*.

It soon struck me that the solution to the problem lay in devising some method whereby the transmitter remained unchanged while the receiver was protected against the influence of the powerful near-by oscillations . . . the problem resolved itself into the question of obtaining a really selective receiver.

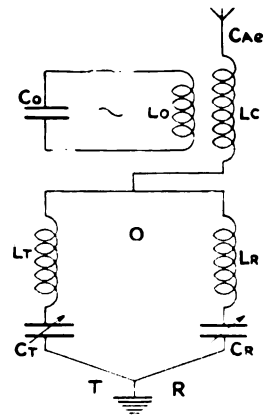

Fig. 3.

As a first step I concentrated on using two aerials side by side, one energised by a transmitter of purely standard design, the other connected to a sensitive receiver working on a slightly different wave from the transmitter, and so selective as to respond only to the one wave and be uninfluenced by the local transmitter either by forced oscillation or low frequency induction. The method of slinging the aerials was simple, and is illustrated in Fig. 2. This method uses but two masts; in fact, the complication of the aerial

* P. P. Eckersley—"Duplex Telephony for Aircraft."—*Proc. I.E.E.*, Vol. 58, p. 555.

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system is hardly greater than if a single system were used.

I found a Navy type rejector properly tuned gave me Duplex by this method. With a 10 per cent. difference of wave-length and a transmitter of from 10 to 20 watts power, provided I took great trouble to screen *all* leads in the receiver, I was able to accomplish Duplex over practical distances. I devised and adapted all the well-known selective circuits, and even invented some that (to me, at any rate), were new; but the essence in all the experiments was the same, to protect the receiver by elaborate shielding and selective circuits. I was partially successful, but never wholly so. The experiments showed that the arrangements for unskilled handling would never develop into anything practical.

I had tried in the meanwhile, and up to a point successfully worked, a single aerial system which relied upon the same principle of protecting the receiver, but did it with one aerial. As this forms the basis for a really successful system afterwards developed, it merits a full description. In Fig. 3 an ordinary tuned circuit is branched into two tail circuits T and R, each containing capacity and inductance. The product L_TC_T is equal to L_CC_{Ae} where C_{Ae} is the aerial capacity, so that if a powerfully oscillating circuit L_0C_0 is introduced as shown and is tuned to L_CC_{Ae} strong currents are set up in the path $L_CL_TC_T$. O becomes a node of potential, and except for potentials introduced by ohmic resistance (as apart from reactive impedance) all the current flows through L_TC_T and none through the differently tuned path L_RC_R.

Again, however, the device was not practical. The transmitting current did from a transmitting point of view confine itself to one leg, but the small component that flowed in the leg C_RL_R was often quite enough, without painstaking balancing, to swamp the received component. Added to this, I had all the troubles of direct "wipe out" and the shielding had to be made painfully elaborate. At one time I thought that the only solution was to clothe the operator in copper gauze! It worked at times, and I was able to signal with a 10 per cent. difference of wave-length over practical distances, but obviously there was no hope of a practical realisation of Duplex Telephony.

It was at this disheartening stage of the proceedings that I left the work, and did not pick it up again for perhaps a year. Meanwhile, Mr. C. E. Franklin had perfected a device for Duplex Telephony (using two aerials) that opened up a new principle, which has proved amazingly useful for medium-powered sets for Duplex working where transmitter and receiver must necessarily be close together. Mr. Franklin's system is briefly as follows: One aerial oscillates at a frequency N_T. A near-by aerial is tuned to receive a frequency N_R. Due to the powerful oscillations N_T in the near-by aerial, the receiving aerial has created in it oscillations N_T and N_R, N_T

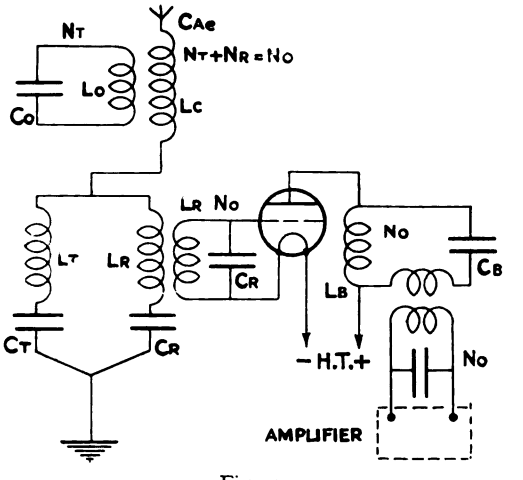

Fig. 4.

being forced from the near-by transmitter, N_R being received from the distant station. These two frequencies beat together and produce a lower frequency N_0, which can be detected and amplified without fear that the amplifier will suffer wipe out from N_T, it being adjusted only to deal with frequencies of the order of N_0, which are far removed from those of N_T or N_R.

Applying this principle to Fig. 3 we see that in the leg L_RC_R we have two components of oscillating current, one of frequency N_T and the other of N_R. A coupled circuit is applied as in Fig. 4, and a rectifying valve produces beat frequency oscillations N_0 in the circuit L_RC_R. Coupled to L_RC_R is another circuit tuned to N_0 and this forms the input to any low frequency or long-wave amplifier. This amplifier, since it deals with beat frequencies N_0

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(or long waves) is immune to the forced or induced effects due to the transmitter.

The system works, and works well, with one aerial, and I have received with perfect clarity telephone signals from 100 miles on an aerial which is oscillating with five ampères current at a 10 per cent. difference in frequency from the received signal.

More simply, one can use two aerials on the same mast as in Fig. 2, when the tail circuits of Figs. 4 and 5 are unnecessary; but for ship and more particularly aeroplane work this arrangement is sometimes impossible, and it is at any rate interesting

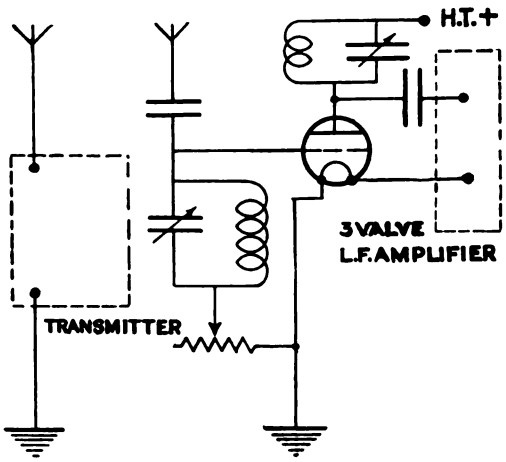

Fig. 5.

to know that my system of the tail circuit can be used. Although one always has a great leaning towards one's own ideas, I think the two-aerial system is better where it can be used.

Mr. N. Ashbridge, my late colleague in an experimental section of the Marconi Company, and now in charge of that section, has devised other and even simpler methods of doing Duplex Telephony for comparatively small power work. Essentially his methods rely upon using two aerials hung as in Fig. 2, but making the receiver so selective as to be uninfluenced by the local transmitter; going back, in fact, to the protected receiver system, and so perfecting the selectivity of the circuits, and so shielding the amplifiers, that with small powers (a few watts) no wipe out is experienced.

The object in view when designing this set was to produce a receiver of ultra simplicity which at the same time was capable of cutting out a small local transmitter.

One circuit adopted is illustrated in Fig. 5. The object in view when designing this set was to produce a receiver of ultra simplicity which at the same time was capable of cutting out a small local transmitter. By this means he was able, working on short wave-lengths, to develop a set which was commercially guaranteed for ranges up to 20 miles. (This means that probably at night, with real pains and a very weak signal, the device might communicate over 200 miles. There is a great deal of difference between an occasional R_3 signal and guaranteed range!)

Further work on similar lines by Mr. Holdridge of the Marconi Company has resulted in a set which is capable of dealing with much larger powers. In this case, however, a really simple circuit is inadequate, and it has been necessary to take special precautions to obtain the necessary degree of selectivity and at the same time obtain a circuit capable of receiving *undistorted* speech.

Turning now from sets in which it is essential to have one operator and both transmitter and receiver side by side, one at once realises that where space is available Duplex presents no serious problem. Captain Round in 1920-21 established two-way communication by telephone over the North Sea, using wave-lengths of 3 per cent separation. His method relied upon frame reception using Armstrong receivers, enabling him to cut out the local station on the frame, and to amplify, thanks to the beat method of reception, at frequencies far removed from those of the transmitter. The receiving and transmitting stations were about 200 yards apart, which further helped to receive without wipe out.

It is obvious that a multiplicity of methods are open to the designer of Duplex systems where large space is available, but the real interest lies in those systems where a single aerial or two aerials close together are a *sine qua non.* I have attempted to outline some few methods of achieving Duplex above, and hope they may have been of interest to readers.

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Notes on Power Transformer Design.

By A. Castellain, A.C.G.I., B.Sc. **[R356**

THESE notes are intended for the amateur who has A.C. mains, and who wishes to obtain fairly large voltages for transmitting purposes. One of the simplest ways of doing this, of course, is to transform up to the required voltage, or half the required voltage, as the case may be, and rectify by means of small chemical rectifiers with the aid of condensers. It is proposed to deal here with a transformer designed for use with a voltage doubling rectifier system, and intended to deliver 200 milliamps at 1 100V and 10 amps at 11V from 220V 50 cycle mains.

It is possible to pick up old transformers which have been used for house lighting for quite a moderate sum and in fairly good condition. This constitutes the cheapest method of obtaining a core of reasonable size. A common size of core is shown in Fig. 1. The cross-section of the core shown in the illustration is 2 in. by $1\frac{1}{3}$ in., giving an area of $3\frac{1}{2}$ sq. in.

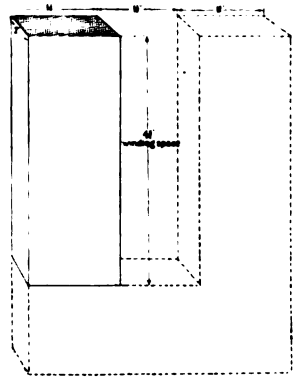

Fig. 1.

Now the fundamental transformer equation is as follows :—

E.M.F. induced per turn $=4{\cdot}44\, f\, A\, B\, 10^8$ volts where f is the periodicity of the supply $=50$.

A „ *effective* core area.
B „ flux density at which the transformer is worked.

The effective core area is taken as 0·9 times the actual core area to allow for insulation between the core plates.

$$\text{Hence, } A=0{\cdot}9\times 3\tfrac{1}{2} \text{ sq. in.}$$
$$=0{\cdot}9\times 3{\cdot}5\times 2{\cdot}54^2 \text{ cm}^2=20{\cdot}4 \text{ cm}^2.$$

A suitable value for the flux density B is 10 000 lines per sq. cm., whence E.M.F. per turn $=4{\cdot}44\times 50\times 20{\cdot}4\times 10^4\times 10^8$ volts $=0{\cdot}45$ volts.

This means that for every turn we put on

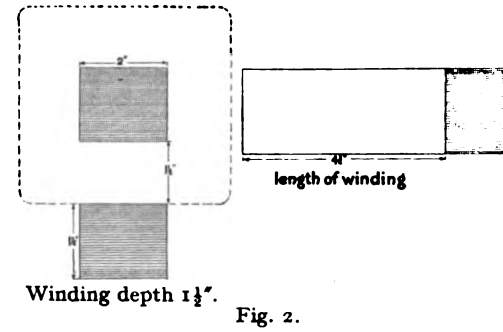

Fig. 2.

the core (assumed to be working at a density of 10 000 lines/cm²) we shall obtain a voltage of 0·45. Therefore the primary turns will be

$$\frac{\text{Primary volts}}{\text{volts per turn}}=\frac{220}{0{\cdot}45}=488.$$

This may conveniently be rounded off to 500 turns, which means that the core will be worked at a flux density slightly lower than 10 000 lines/cm².

The secondary turns will be

$$\frac{\text{Secondary volts}}{\text{Primary volts}}\times \text{Primary turns}$$
$$=\frac{1\,100}{220}\times 500=2\,500 \text{ turns.}$$

The turns for the 11V winding will be

$$\frac{11}{220}\times 500=25.$$

We now know the number of turns in the winding, so the next thing to be done is to get them into the space available.

It is very convenient to sectionalise the windings, as the experimental value of the transformer become smuch greater—*i.e.*, various different voltages can be obtained from the same transformer. If we make

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the primary (500 turns) five coils of 100 turns each; the secondary (2 500 turns) five coils of 500 turns each; and the tertiary (25 turns) —say, one coil 12 turns and one coil 13 turns, we can obtain voltages of 5, 6, 11; 44, 88, 132, 176, 220; 220, 440, 660, 880, 1100.

Again it is wise to alternate primary and secondary coils so that, in this case, five coils for each is quite suitable. Hence the winding length will be occupied as follows :—

5 secondary coils each — wide total		x
5 primary coils	,, — ,, ,,	y
2 tertiary coils	,, — ,, ,,	z
13 thicknesses of insulation each 30 mils..... (approx.) total 0·4 in.		
	Total	4·75 in.

The 11V winding has to supply 10 amps without undue heating. From the London Electric Wire Co. and Smith's tables it is seen that gauge 12 wire will carry 12·868 amps at the 1 000 amp per sq. in. rating. Two thicknesses of gauge 12 D.C.C. wire come to 0·23 in., leaving 4·75—0·4—0·23 in. =4·12 in. for the primary and secondary coils.

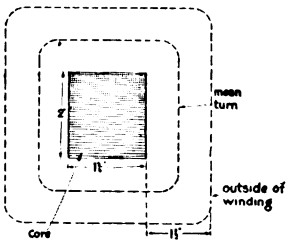

Fig. 3.

Length of mean turn of coils=

$$2\left[(1\tfrac{3}{4}+1\tfrac{1}{2})+(2+1\tfrac{1}{2})\right] \text{ ins.} = \underline{13\tfrac{1}{2} \text{ in.}}$$

Total length of primary wire $=\dfrac{500\times 13\frac{1}{2}}{3\times 12}$ yds.

=188 yds.

Total length of secondary wire is

5×188 yds.=940 yds.

The secondary has to deliver 200 milliamps. Referring again to the wire tables, it is seen that gauge 27 or 26 is suitable.

The primary current may be taken as

$$\frac{\text{Secy. current} \times \text{secy. volts}}{\text{Primary volts}} + 25\% \text{ for losses;}$$

i.e., in this case it is $0{\cdot}2\times 5+25$ per cent. =1·25 amps, for which 19 gauge wire is suitable.

Diameter of 19 gauge wire, D.C.C. 0·048 ins.
,, 27 ,, ,, ,, 0·0246 ,,
,, 26 ,, ,, ,, 0·026 ,,

Gauge 26 is to be preferred from the point of view of ease of obtaining it.

Winding depth available 1·5 in. Allowing for core and winding insulation we will allow a maximum depth of coil of 1·4 in.

Dealing with the secondary winding first :—

No. of turns of 26 gauge wire in 1·4 in.=

$$\frac{1{\cdot}4}{0{\cdot}026}=54.$$

Hence the secondary coils may have 54 layers, and since 2 500 turns are required, there must be

$$\frac{2\,500}{54}=46{\cdot}3 \text{ turns per layer.}$$

Having judged what the secondary winding should be, we may now round off the number of layers to 50, thus making the turns per layer 50 also, or the turns per coil per layer 10, which is most convenient. The total width of the secondary winding is $50\times 0{\cdot}026$ in.=1·3 in.

Similarly for the primary winding, the number of layers possible is

$$\frac{1{\cdot}4}{0{\cdot}048}=29.$$

Taking 25 layers we get

$$\frac{500}{25}=20 \text{ turns per layer or 4 turns per layer per coil.}$$

Total width of the primary winding= $20\times 0{\cdot}048=0{\cdot}96$ in.

Combined width of primary and secondary $=1{\cdot}3+0{\cdot}96=2{\cdot}26$ in.

Combined width of primary, secondary and tertiary$=2{\cdot}26+0{\cdot}23=2{\cdot}49$ in.

We actually have a maximum of 4·75—0·4 =4·35 in. of winding space at our disposal.

Hence the number of turns may be increased in the ratio

$$\frac{4{\cdot}35}{2{\cdot}49}=1{\cdot}74.$$

We will therefore increase the number of turns by half as much again, and make up the remaining winding length with insulation. This increase in the number of turns on the three windings does not alter the voltage ratios between them, but it lowers the flux density and hence the iron losses at which the core works to $\frac{1}{1{\cdot}5}$ of its original value, *i.e.*, to about 6 700 lines/cm². This method of first designing the winding using a high flux density and then increasing the number of turns so as to fit the winding space available, and thus lowering the flux density, will be found very useful when it is desired to fit a winding on to a given core.

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The final design of the transformer windings is thus as follows :—

Primary.—Total turns *750*. Made up of five coils of 25 layers, each having 6 turns per layer. Gauge of wire S.W.G. 19.

Secondary.—Total turns *3750*. Made up of five coils of 50 layers, each having 15 turns per layer. Gauge of wire S.W.G. 26.

Tertiary.—Total turns *38*. Made up of three coils, 13, 13, 12 turns of 12 gauge wire. Centre coil tapped 5th turn.

Flux density in core.—6 700 lines/cm².

Total length of primary wire $188 \times 1{\cdot}5 = 282$ yds.

Yards per lb., gauge 19=68 yds.

Weight required $= \frac{282}{68}$ lb. $= 4{\cdot}15$ lb.

Total length of secondary wire 5×282 yds. $= 1\,410$ yds.

Yards per lb., gauge 26=340 yds.

Weight required $= \frac{1\,410}{340}$ lb. $= 4{\cdot}15$ lb.

Total length of tertiary wire

$$\frac{38 \times 13\frac{1}{2}}{36} \text{ yds} = 14\tfrac{1}{2} \text{ yds.}$$

Yards per lb., gauge 12=10 yds.

Weight required $= 1\frac{1}{2}$ lb.

Total insulation space $= 4{\cdot}75 - (1{\cdot}5 \times 2{\cdot}49) = 1$ in. (very nearly).

Total number of thicknesses of insulation required=14. (The extra one is necessary as there are now three tertiary coils instead of the two previously allowed for.)

Hence thickness of insulation may be

$$\frac{1}{14} = 0{\cdot}07 \text{ in. approx.}$$

The approximate cost of the windings is as follows :—

					s.	d.
$4\frac{1}{4}$ lb.,	19 gauge,	at	1/11	per lb.=	8	2
$4\frac{1}{4}$,,	26 ,,		3/4	,,	14	2
$1\frac{1}{2}$,,	12 ,,		1/3	,,	1	$10\frac{1}{2}$
					24	$2\frac{1}{2}$

It is quite possible to improve on this cost—especially in the matter of the 26-gauge wire, which can be obtained very cheaply at present.

If this article has shown anybody how to design a transformer to suit his own needs, then it has served its purpose.

Radio in New Zealand. [R090·9

ALTHOUGH New Zealand is far away around the other side of the globe from the great centres of population and the huge factories and laboratories for manufacturing and research, still the fascinating science of radio has taken a great hold on the people of this country, and enthusiastic "fans" of various ages and occupations are numbered by the thousand.

There are several radio stations in New Zealand, erected by the Government and operated by the Post and Telegraph Departments for the conduct of radio communication to and from New Zealand, and between the stations themselves. The Awanui station is situated in the "far north," and Awarua in the south and spaced between these extremes are the four large cities—Auckland, Wellington, Christchurch and Dunedin—each with its own station. These Government stations confine themselves to morse, leaving wireless telephony to the broadcasting stations.

In most towns of any size in New Zealand, broadcasting stations have been erected. None, however, are of considerable power, 100 watts probably being a maximum, and the majority being under 10 watts. All the broadcasting stations in New Zealand are owned and operated by private individuals, or by combinations of dealers in various centres. This service is gratuitous, the only recompense these enterprising enthusiasts receive being that feeling of satisfaction that comes from having done something for the good of the science one is interested in; and to the dealers, the impetus that good programmes properly broadcasted give to the sales of radio parts.

The Government issues licences to those who apply, pass a test, and pay a fee, but there is a very large number of listeners who so far have not registered. Everyone realises that these haphazard conditions cannot long continue; but in the past there has been a holding off, due no doubt to a

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feeling that what may be decided on to-day may be obsolete by the time the plan is put into operation, consequent on the rapid development during the last year or so.

Latest reports, however, indicate that an arrangement has been effected between the Government, the dealers and the amateurs by which a big broadcasting company is to be formed to control and operate broadcasting in New Zealand. The proposed scheme provides for the installation of a 500-watt broadcasting station at each of the four New Zealand main cities—Auckland, Wellington, Christchurch, Dunedin. These stations will operate simultaneously, but on different wave-lengths, and will commence broadcasting in the early afternoon and continue till 11 p.m. One "silent night" will be observed in each week to permit amateur transmitters to work. When the scheme materialises, listeners possessing up-to-date sets will have an excellent choice of programmes and it is anticipated the number of devotees will be greatly increased. It is expected the licence fee will be about 25s. per year, payable to the Government, and registration will be compulsory. Of this amount, three-quarters will go to the Broadcasting Co., and it is anticipated this will afford sufficient revenue for a really first-class service. Professional talent will be engaged and arrangements made for these artists to tour the circuit of the four stations.

New Zealanders are taking a keen interest in the new stations recently erected in Sydney, Australia—1 000 miles due west of New Zealand—by Farmer & Co., and by Sydney Broadcasters, Ltd., the former sending on 1 100 metres and the latter 350 metres. Both stations have been picked up, but owing to 1 100 metres being beyond the usual broadcasting band of wave-lengths, many owners of receiving sets cannot "tune in" Farmer & Co.

The more experienced amateurs are having considerable success in the reception of long-distance music and speech, particularly from California. One man at Hamilton, an inland New Zealand town, using a 3-valve reflex set, recently heard a number of instrumental items, one song and the announcement "6XJ, General Electric Co., 555, 14th Street, Oakland, California."

Our regulations allow of latitude in regard to the circuits we may use, but not so much as is permitted in U.S.A. For instance, we may use the three-coil regenerative circuit—in fact, this is the one most generally used—but we may not connect "grid" direct to "aerial." In consequence of these differences in allowable circuits, many arrangements recommended in English and American radio journals are not available to us. A very popular circuit in New Zealand is the "Cockaday DX Bringer-in," a desirable feature of which is the provision for changing the inductances, enabling the tuning in of Farmer & Co., the 1 100 metre Sydney station. In this respect this circuit is more suitable than the famous "Cockaday Four Circuit Tuner."

New Zealand is well supplied with radio literature, and the leading radio magazines from America, England and Australia are in evidence in every radio-dealer's shop. In addition, there is a good assortment of text-books, but, naturally, dealers are chary of carrying a heavy stock of these, as they are apt to become obsolete so quickly.

The Auckland Radio Association has under consideration the formation of a technical and research branch, and should this materialise and the members devote themselves seriously to the work, much useful information should result.

Radio instruments and material used in this country are practically all imported, the bulk coming from U.S.A., Canada, and England, and in a lesser degree from France. Dull emitter valves have received an enthusiastic welcome, as they render unnecessary the use of accumulators required with the older types, which were always a source of anxiety, particularly to country users, owing to the inconvenience of getting them recharged.

As some of our readers will be aware, direct two-way amateur communication has now been established between New Zealand and this country. Up to the day of writing, the results are, briefly :—

Oct. 16, 6.30 a.m., 2OD (E. F. Simmonds, Gerrard's Cross) heard Z4AG.

Oct. 17, early morning, Z4AA heard 2OD.

Oct. 18, 2FZ (C. W. Goyder, Mill Hill) worked Z4AA.

Since then, 2NM (G. Marcure, Caterham), 2OD, and 2KF (J. A. Partridge, Collier's Wood) have worked with one or more of Z4AG, Z4AA, Z4AK.

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Radio 5US. An Amateur Station.

By J. Croysdale, B.Sc. [R612

THOUGH placed rather at a disadvantage as regards geographical position and availability of public supply mains, a considerable amount of experimental work has been carried out at 5US. Judging by the distances which have been covered and reports on transmissions received from other stations, a fair degree of efficiency may be claimed.

5US is located at Burley-in-Wharfedale, Yorkshire, 250 feet above sea level. The surrounding district is very hilly, and the station, situated in a valley, is badly shielded by the hills of the Pennine Range, which lie to the west. This fact, coupled with the immediate neighbourhood of the station, render the aerial site far from the ideal for transmission purposes.

A great deal of time has been spent on experiments with different forms of aerials on the short waves. The single wire, "sausage," fan, and flat-top have been tried in turn, and the conclusion arrived at so far is that the flat-top gives the best all-round results, expense being an important consideration. The aerial in use at the moment is a twin wire inverted L. The dimensions are given in Fig. 1, which should suffice without further description.

As in the case of the aerial, many forms of counterpoise have been tried. Tests in this case have been governed by the exigences of garden space and the risk of upsetting domestic arrangements. However, an erection which gives fair results has been made.

The wires of the counterpoise, four in number, pass very near earthed objects at irregular distances. Two of the wires pass through small shrubs and on this account they are made of insulated lighting cable. A source of much annoyance is a 30-ft. fir tree which sprouts through the centre of the counterpoise and does its best to reach the aerial; consequently, some dielectric losses are to be expected!

In addition to the counterpoise, an earth connection is utilised in the transmitter. This earth is a soldered connection to the water main which runs up under the garden parallel with the counterpoise.

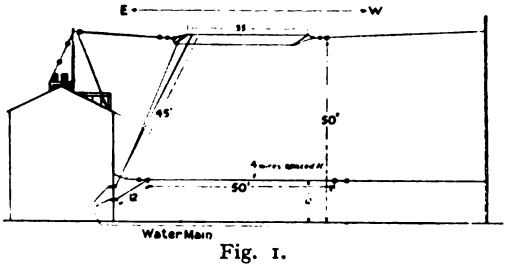

Fig. 1.

The transmitting circuits are continually altering, and the changes have been rung on "Colpitts," "Meissner," "Hartley" and the rest, with innumerable modifications. The circuit now being used is the ordinary "reversed feed back," as it is often called. This appears to be as efficient as the others, particularly when used in the form shown (Fig. 2).

Owing to the aforementioned fact that there is no electric main available, also the expense of a generator being prohibitive, an ex-Government T.V.T. unit was tried as a source for long-distance C.W. work. This has given quite a satisfactory performance, as a result these notes have been written mainly for the information of those who may be interested in this form of high tension supply.

The construction and mode of operation of the T.V.T. unit will be known to most experimenters. The current as delivered from the secondary winding is, of course, a semi-A.C. and applied direct to the valve

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gives an I.C.W. note. This note, though carrying very well and clear to read was found to give considerable jamming to weak amateurs on account of the flatness of tuning. Means were then sought whereby this "blotting out" of local receivers might be eliminated. Methods of rectification were tried with a view to obtaining pure c.w. Neon tubes and valve rectifiers were tried but did not warrant the power absorbed. It was decided to stick to the original I.C.W. but to try to sharpen up the emitted wave.

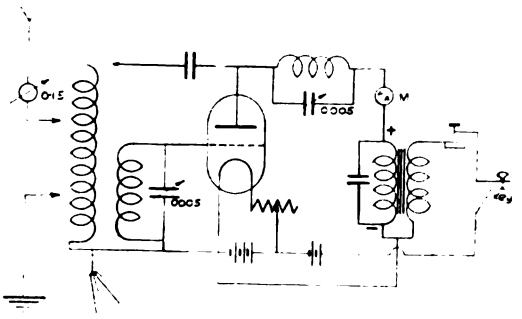

Fig. 2.

This was achieved by using shunt supply to the valve and including a radio-frequency choke in the plate lead; this choke to be tuned with a variable condenser to syntony with the wave-length of the aerial circuit.

The wave was considerably sharpened; to such an extent, in fact, that stations a few miles away who before were helpless over 15° of A.T.C. were now able to cut out the signals sharply with 2° condenser.

Trouble might be expected, perhaps, from the interrupter of the T.V.T. not keeping a steady frequency. But this rarely occurs if the contacts are kept reasonably clean and the valve in use is bright enough to absorb all the current from the secondary.

The transmitting apparatus is shown at the left hand end of the bench (Fig. 3). The aerial inductance may appear somewhat cumbersome. This consists of 32 turns 7-22's stranded aerial wire, spaced $\frac{3}{4}$ in., wound on a cylinder 6in. diameter. In order to limit the absorption losses due to earthed objects in its field the A.T.I. is supported well away from the wall and bench. The grid-coil, 20 turns of 18 S.W.G., is tapped and moves inside the A.T.I.

The T.V.T., is under the bench in a padded cradle to reduce to a minimum the buzz of the contact breaker. One has to fit a silencer like this when working in the small hours of the morning.

The tuned radio-frequency choke is wound with 30 turns 24 S.W.G. on a 3-in. tube, and tuned with a ·0005 mfd. condenser. The anode stop condenser was made in the conventional way from copper foil and old photographic plates. It has a capacity of ·002 mfd.

On considering the transmitting circuit, it will be noticed that a combination of direct ground and counterpoise is used. The earth tap is set approximately at the voltage node in the aerial inductance. The method of adjusting for the nodal point is as follows: The transmitter is tuned up for maximum aerial current at the required wave-length. The earth tap is then applied to the bottom of the A.T.I., and in steps moved towards the aerial tap, and each time the aerial current increase or decrease noted. A point will be found, at either side of which there is a decrease in current. The point varies, of course, for different wave-lengths.

Before going on to details of the receiving side it might be mentioned that little telephony has been carried out; and this only on very low power. Using a simple "tickler" circuit with grid modulation and 50 volts on an Ediswan A.R. valve good speech was received by 2VO on two valves at 12 miles.

Fig. 3.

To the immediate right of the transmitter will be seen a receiver. This is a single valve "super" and has been used off and on for the last two years for DX work. Quite a few American amateur stations have been logged using only a 4-ft. frame. For general

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reception and comparative purposes the orthodox reaction circuit is used. A super-heterodyne is now being built for working Australia.

Although 5US has not so far been logged the other side of the Atlantic, some long distance transmissions have been made which show that, at any rate in some directions, the signals should be good for a few thousand miles. Two-way working has been carried out with Finnish 1NA, 3NB, and 2NM and each has reported R-6. The aerial current at this end was 0·25—0·3 and the distance 1 200 miles.

Interesting phenomena have been observed in relation to the shielding effect of the local hills. In particular, signals have been exchanged with 7QF, Copenhagen, at 3.30 p.m. G.M.T., signal strength, R-6. Yet, later the same night, reports from a station to the west were R-3 to R-4; the distance being only 70 miles as against 500. This weakness to the west is always prevalent while signals at the same time anywhere east up to 500 miles are R-7 or so. Whether this shielding is purely local and that the waves are merely deflected or not would be interesting information.

The directional effect of such an aerial as described above may account to some extent for these variations. The combination of aerial and counterpoise with earth tap at the potential node would tend to give directive properties, particularly to an aerial worked in the neighbourhood of its fundamental.

Some details regarding aerial currents obtained with varying inputs to the T.V.T. may be of interest. A Mullard 0-30 A valve is used on the transmitter. Taking the efficiency, input to output, of the T.V.T. to be approximately 33 per cent., with an input of 10 volts, 3 amps to the primary, an input of 10 watts is obtained. This gives an aerial current of 1 amp on 170 metres. Using 6 volts at 2 amps to the T.V.T., *i.e.*, 4 watts to the valve, the current is 0·5 to 0·6 amps.

Reports are always welcome from anyone who hears transmissions from 5US.

Short Wave Receiver Notes.

By R. A. Farmery. **[R402**

Another contributor here expresses a view in favour of L.F. amplification for short-wave work.

SINCE the phenomenal successes which attended the use of very short waves in the Transatlantic tests of 1923-24, more and more attention has been given by experimenters to the design of short-wave receivers. The building of a successful receiver to work on a wave band of say 75 to 250 metres is by no means a simple task, and the writer makes no apologies for offering a few practical notes on the subject.

Before commencing a more detailed examination it is perhaps as well to ascertain the fundamental requirements of such a receiver as we propose to build. In the first place then, since the set is presumably to be used for DX work, it *must* be easy to handle, secondly, it must be sensitive, thirdly, it must be selective, and, lastly, it must be as free as possible from parasitic noises. Whilst this by no means exhausts the list of desirable features it covers the ground fairly well, and at the same time provides us with a quite sufficiently difficult task.

If we omit "super" (?) circuits we have five possible means of achieving our object: (1) Detector alone; (2) H.F.—Detector; (3) Det.—L.F.; (4) H.F.—Det.—L.F.; and (5) Supersonic Heterodyne.

Of these five methods the last is, undoubtedly, the best, but as only relatively few of us can afford to use it, it is not proposed to deal with it in this article.

The question of high frequency amplification on short waves is one which has raised considerable controversy in the United States, but the general opinion over there seems to confirm the writer's own impression that below 300 metres high frequency amplification is a waste of time, money and valves. Whilst this statement may appear to be somewhat sweeping, it is based on several years' short-wave experience; and, although efficient amplification at these high frequencies is possible, it is

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undoubtedly gained at the cost of so complicating the apparatus as to render it useless for quick changes of wave-length.

The addition of one or two stages of note magnification can be made without any sacrifice in simplicity, and in this way a very considerable increase in the effective range of the station may be made.

It may be pointed out, in passing, that it is quite fallacious to assume that low frequency amplification does not increase range. It is quite possible for a signal to be of sufficient strength to produce rectification and yet to be insufficient to produce an audible movement of the telephone diaphragms. In this case the addition of L.F. valves renders the signal audible and so increases the range of the station. Five minutes' experimenting with a Det.—L.F. receiver fitted with switching for the L.F. valves is sufficient to convince one of this.

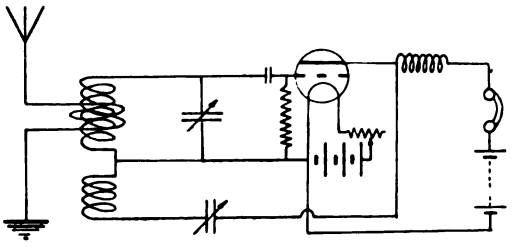

Fig. 1.

It is very questionable, however, whether, for all ordinary purposes, it is worth while to use more than one stage of note magnification since to do so not only makes most signals unnecessarily loud, but also appears to amplify static and inductive disturbances to a much greater extent than the desired signals. Moreover, on the grounds of selectivity, it is not advisable to make signals too loud since the human ear is better able to differentiate between two weak sounds than two loud ones. If it is decided to use more than one stage of low frequency, switches should certainly be incorporated in the set to cut the additional stages in or out as may be required.

Since it is somewhat difficult to make a directly-coupled receiver oscillate at frequencies of the order of 4×10^6 ($75m$) it is almost essential to use some form of loose coupling. The simultaneous adjustment of two tuned circuits is, however, rather a difficult task on these very short wave-lengths, and, in order to keep the receiver as simple as possible the author is strongly in favour of making the aerial coil aperiodic. This is a point however which everyone may best decide for himself, and in districts where "mush" is bad it would be advisable to try out both systems with a view to ascertaining which is least susceptible to this form of interference.

The ordinary loose-coupled receiver works quite well down to the lowest wave-length on which we wish to receive, *i.e.*, $75m$. It is advisable that reaction should be taken to the aerial coil and not the secondary as this has a great effect both on the stability and ease of control of the receiver.

The inductances may in this case consist of a set of purchased extra-short-wave coils, but more efficient results are generally obtainable with homemade coils. It will be remembered that the present type of plug-in coil was originally designed to provide a compact inductance for long-wave work, and that no special care was taken to keep the capacity of plugs and mountings as low as possible. The consequence is, that the capacity in the coil plug, together with that of the coil holder and its attendant leads, is very considerable, and is, in fact, far too great to be really efficient on short and very short waves. If maximum efficiency is aimed at, the single layer coil wound with turns slightly spaced cannot be improved on.

A circuit which has given excellent results is shown in Fig. 1. This is a sort of loose-coupled Reinartz, with aperiodic aerial coil. Whilst no claims are made as to the novelty of this arrangement, the writer does not recollect seeing it described elsewhere.

Although some difficulty was at first experienced in obtaining a smooth control of reaction, this arrangement has proved to be the most satisfactory yet tried. It should be noted, however, that at wave-lengths near the fundamental of the aerial it is decidedly bad to make oscillate. This was overcome in the present case by erecting a special 45 ft. aerial from the operating cabin to the top of the mast. Using this aerial splendid results have been obtained, and it appears to be quite large enough for short-wave work.

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Valves Tested. [R330-09

This month we have had a most interesting and diverse set of valves for testing.

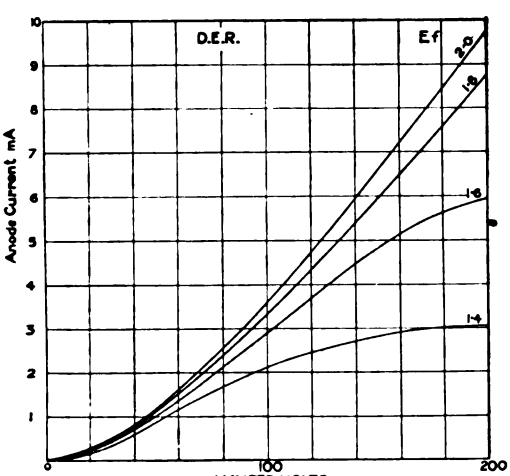
OWING probably to the fact that there was already rather a heavy batch of work in the test room this month, seven valves came along. However, we have struggled against fate, and here follows an account of their characteristics.

We will deal first with a whole bunch of Marconi-Osram valves: the D.E.R., D.E.6, D.E.4, D.E.5b, and D.E.7.

D.E.R.

This is, of course, by no means a new valve, but, curiously enough, we have not previously had one available for taking accurate characteristics.

It was one of the first, if not *the* first, British dull emitter, and is described as a general purpose valve, rated at 1·8—2·0V, 0·4A, anode 30—50V. It will be remembered that the earlier types had vertical electrodes. This is now changed, the electrodes being arranged as in the old "R," but a little smaller.



The valve was tested at 1·4, 1·6, 1·8 and 2·0V, on the filament, and its constants will be gathered from the accompanying table. The first exceptional point is the very large output, this being 10mA at the lower rated voltage, and no less than 19 at 2·0V. In fact this valve should be just large enough to handle a small loud-speaker.

The anode impedance is satisfactorily low, especially in view of the magnification, which is quite high (8·5). The combination leads to a very good figure (3—4) for the power amplification.

Fil. Volts. E_f	Fil. Cur. I_f	Sat. Plate Cur. I_s	Anode Impedance. R_a	Voltage Ampli. μ	Power Ampli. P $\left(=\frac{1\,000\mu^2}{R_a}\right)$	Filament Efficiency F $\left(=\frac{I_s}{\text{Watts.}}\right)$
V.	A.	mA.	O.			
1·4	·35	3	61 000	8·5	1·2	6·1
1·6	·375	6·1	30 000	8·5	2·4	10
1·8	·4	10	21 500	8·5	3·4	14·
2·0	·45	19	18 500	8·5	3·9	19

The "filament efficiency," *i.e.*, mA of output per watt input, is about half that of the maximum obtained with "super-efficient" valves.

From the set of curves shown we see that the valve should be worked at a steady current of 2mA at least for small input, and say 4 for loud-speaker work; this would correspond to 80V anode and — 1V grid for ordinary work, and say +120V anode and — 3V grid for a small loud-speaker. Price, 21s.

D.E.6.

This is quite a new valve, being designed as a small dull-emitter power valve to operate off a two-volt battery in conjunction with the D.E.R. The electrodes are apparently quite similar, but the performance gives a clue to the probable differences, as will be seen.

The valve, like the D.E.R., was tested at 1·4, 1·6, 1·8, and 2·0V on the filament. The filament current is almost exactly the same, the difference being no greater than that often found between specimens of the same type. The saturation current is greater, rising to 26mA, with a corresponding increase in filament efficiency. This might be due to running the filament hotter, but is not as far as the eye can judge.

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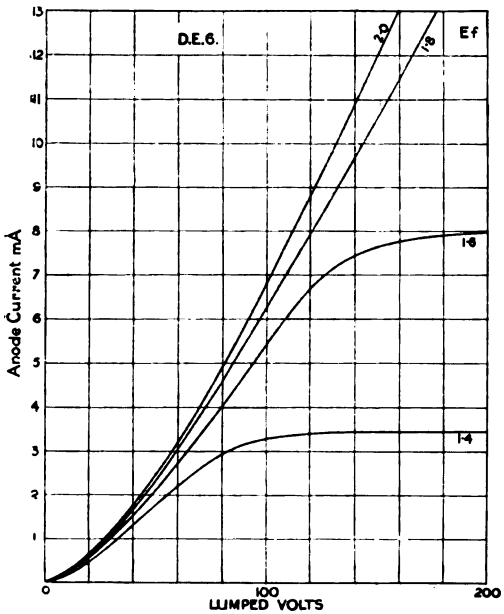
The anode impedance is considerably lower, as will be seen, as is also the magnification: this combination inclines us to



believe that the valve is substantially the D.E.R. with a rather more open grid. The curves show a most satisfactory extent of

Fil. Volts. E_f	Fil. Cur. I_f	Sat. Plate Cur. I_s	Anode Impedance. R_a	Voltage Ampli. μ	Power Ampli. P $\left(=\frac{1\,000\mu^2}{R_a}\right)$	Filament Efficiency. F $\left(=\frac{I_s}{\text{Watts.}}\right)$
V.	A.	mA.	O.			
1·4	·37	3·4	28 000	5·1	·9	6·6
1·6	·39	8	16 500	5·1	1·6	13
1·8	·41	14	12 500	5·1	2·1	19
2·0	·43	26	11 000	5·1	2·4	30

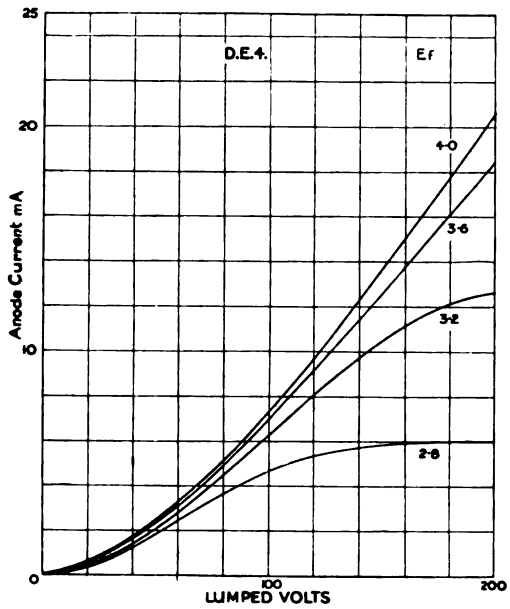
"straight." It would appear that first-class tone for moderate loud-speaker strength would be got with about 90 volts anode, —3V grid, giving a steady current of about 4·5mA. This low voltage is a great convenience.

Price, 25s.

D.E.4.

This is a modification of the well-known D.E.5, being essentially a dull-emitter power valve of large output, but differing from the D.E.5 in its filament, which is designed to operate off a 4-volt battery in conjunction with valves of the 60mA type. It is rated at 3·6V, ·32A, anode 60—120V.

In general appearance it is exactly similar to the D.E.5, with the same hairpin filament and flat grid and anode. We tested it at



2·8, 3·2, 3·6, and 4·0V, and the results appear in the table. It will be seen that the output is fully up to that of the D.E.5, reaching 50mA at 4·0V. The anode impedance, on the other hand, is rather higher, though still very low. It falls to 9 300 ohms at 4·0V, the D.E.5 falling to 6 000 at 5·5. The μ is similar in both valves—about 7.

In the last column we see that the mA per watt of filament input reaches 36, about the same value as in the most efficient 60mA valves.

Fil. Volts. E_f	Fil. Cur. I_f	Sat. Plate Cur. I_s	Anode Impedance. R_a	Voltage Ampli. μ	Power Ampl. P $\left(=\frac{1\,000\mu^2}{R_a}\right)$	Filament Efficiency. F $\left(=\frac{I_s}{\text{Watts.}}\right)$
V.	A.	mA.	O			
2·8	·29	6	15 500	7	3·1	7·5
3·2	·31	12·5	11 000	7·05	6·5	12·5
3·6	·33	25	10 000	7·1	7·2	20
4·0	·35	50	9 300	7·15	7·7	36

Our curves show a very satisfactory performance. For a large loud-speaker, allowing 5V amplitude on the grid, it would be advisable to allow a lumped voltage of 115, or say 140V anode and —5 grid.

Price, 30s.

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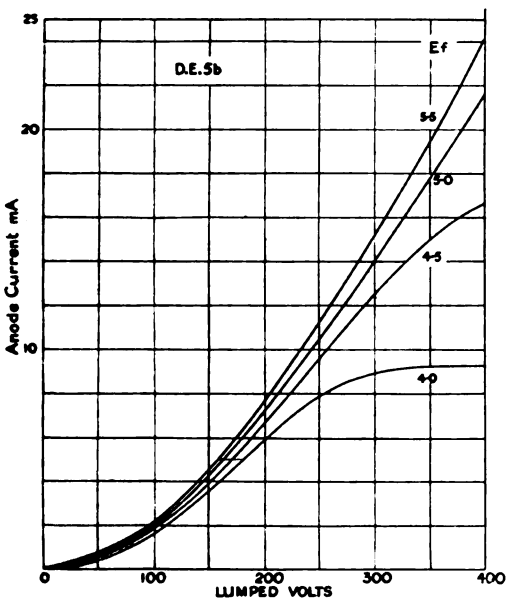
D.E.5b.

Here we have another modification of the D.E.5. In this case the change is in the grid, the valve being specially designed to give very high magnification, for use in resistance-coupled amplifiers, in which the consequent rather high impedance (for a large power valve) is of little importance.

It is built like the D.E.5, except for the grid, and, like it, is rated 5 to 5·5V, ·22A, anode 100—120V.

We tested it at 4·0, 4·5, 5·0, and 5·5V, with the results shown. As regards the saturation current at 5·5 filament volts, it is probably a little more; but owing to the large output and close grid, we reached the limit of available battery power before definitely saturating.



The anode impedance is seen to be of the amount usually associated with an ordinary small valve (30,000—20,000); but it is extraordinarily low in view of the μ of over 20. The filament efficiency is of the usual order for the D.E.5 filament.

We give the "power amplification," which is very high. But when we examine the curves we see that the valve is essentially designed for resistance amplification. Special steps would have to be taken for transformer work. The curves, as they stand, do not begin to straighten till the point corresponding to about 200 lumped volts. Owing to the high μ, an input of 3V grid amplitude would necessitate the total voltage being 320V or thereabouts, with —3V grid: the steady current would be about 11mA.

But for the purpose for which it is designed, we can reckon that the resistance coupling before it will only give 1 to 2 volts amplitude, and the "straightening" effect of a resistance

Fil. Volts. E_f	Fil. Cur. I_f	Sat. Plate Cur. I_s	Anode Impedance. R_a	Voltage Ampli. μ	Power Ampli. P $\left(=\frac{1\,000\mu^2}{R_a}\right)$	Filament Efficiency. F $\left(=\frac{I_s}{\text{Watts.}}\right)$
V.	A.	mA.	O.			
4·0	·2	9·5	28 500	22·6	18	12
4·5	·21	18	22 500	21·2	20	19
5·0	·225	32	20 500	20·6	20·5	27
5·5	·24	45*	19 500	20·4	21	34

* Doubtful.

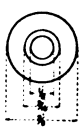
in the anode circuit will also come into play. Under these circumstances, the makers' rating of 120V anode, —1·5V grid would probably suffice; this would give about 2mA steady. But we would prefer 120V on the anode itself, giving 3mA. Allowing for the external anode resistance (say 50 000 ohms) this would necessitate about 200 volts in all. Tested in this way the valve gave most excellent results.

Price, 35s.

F.E.3.

Great interest is now being taken in the 4-electrode valve, and the Marconi-Osram Co. have naturally developed a type to meet it. It will be remembered that they have long had such a valve in use on their reflex ship set. This, however, was designed for a special fitting on V24 lines. The F.E.3, on the other hand, fits the usual 4-pin holder, the inner grid being brought out to the cap, to which a terminal is fitted.

The electrodes are horizontal, and their dimensions are shown approximately in our sketch. We have not the exact sizes, and, needless to say, do not propose to break the valve to measure them! The two grids, within 1/32 in. or less from one another, are a splendid example of skill in valve making. The filament is a normal bright one.



In default of any better method of trying out a four-electrode valve, we tested it for performance, firstly as a "low H.T."

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valve, with the inner grid at a constant positive potential; and second as a reflex valve; input to inner grid, or output from outer

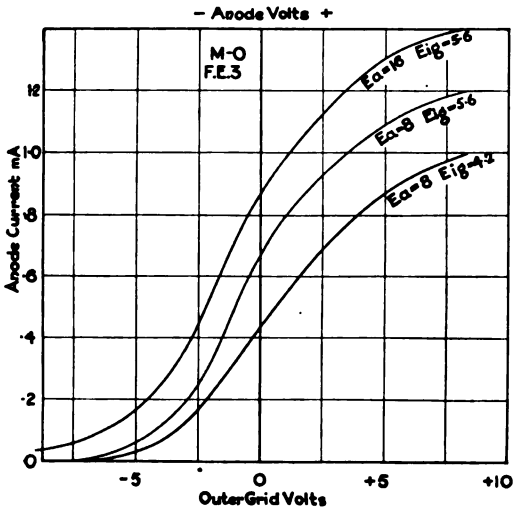

Fig. 1.

grid, and plate as a rectifier. The filament was worked at 3·8V throughout.

Tested first for low anode volt working, we obtained the curves of Fig. 1. These

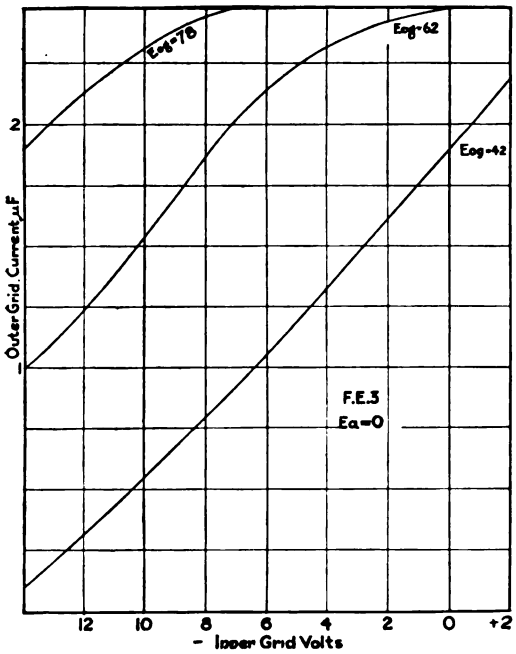

Fig. 2.

show the normal effect of increasing the IG volts—similar to more filament heat. The upper two curves, at the same IG volts, but different anode volts, show an increased saturation. It is probable that the correct

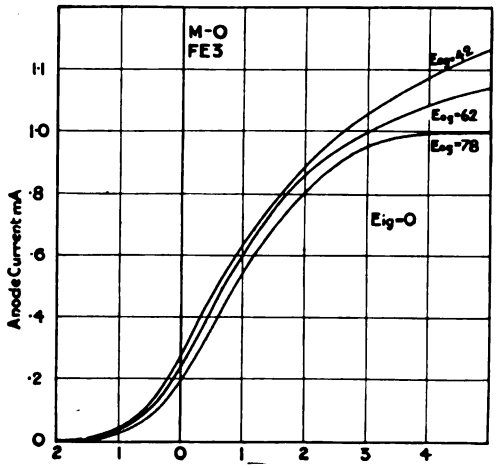

Fig. 3.

anode voltage under these conditions is rather higher than 16. From the curves we find $\mu=5{\cdot}5$, $R_a=42\,000$.

Next, we took the two sets of curves needed for the Marconi dual circuit. Fig. 2 shows the effect of using OG as output and IG as input. Owing to the fact that the two grids are close together, the magnification is low—it is equivalent to having grid close to anode in a three-electrode valve. The actual values found from Fig. 2 are: $\mu=2{\cdot}8$, $R_a=19\,000$.

As is well known, in this layout the anode circuit is the rectifier, with only a small voltage. Fig. 3 shows its behaviour. Obviously there will be good rectification with about —1V on the anode.

Altogether, however, it is doubtful whether either of these circuits is best suited to the F.E3. We are inclined to think that it might function best as a dual with H.F. input on one grid, L.F. on the other, and output from the anode.

Price, 27s. 6d.

We are informed that a similar valve with dull-emitter filament is also available, known as the D.E.7. We hope to report on this later.

A Mullard Four-electrode Valve.

Another interesting valve just to hand is the D.G. (Double Grid) of the Mullard Co. This, like the F.E.3 mentioned above, uses the four-pin holder. A short lead is soldered to the cap, which is connected to inner grid.

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The electrodes are of the new ∩ shape just adopted by the company, their approximate dimensions being shown in Fig. 5.

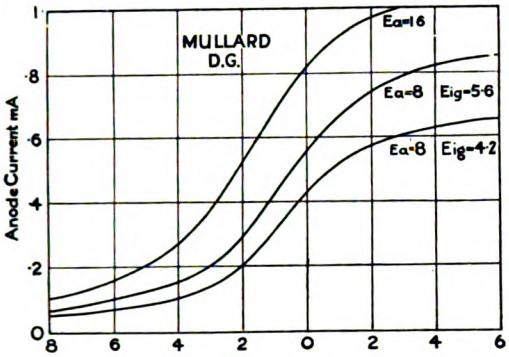


Fig. 4.

The input rating is that usual for bright filaments. It was tested at 3·8V.

Tested for work with low anode volts, the results were as shown in Fig. 4. The curves are normal, except for the curious way in which a small anode current still passes even at quite low grid volts. The "saturation" of 1mA is about that usually given under these conditions. The constants worked out for the two curves with IG at 5·6V are $\mu=5$, $R_a=33\,000$.

Fig. 5.

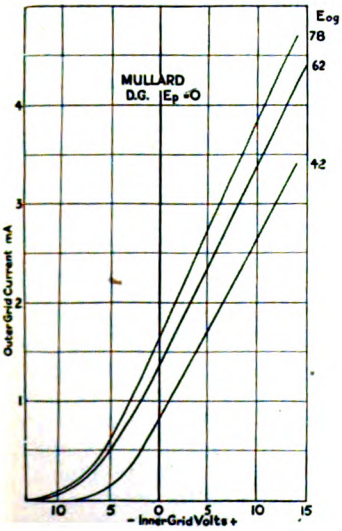


Fig. 6.

With the anode held at 0V, input to IG and output from 0G, the valve behaved exceedingly well, as will be seen from Fig. 6. The

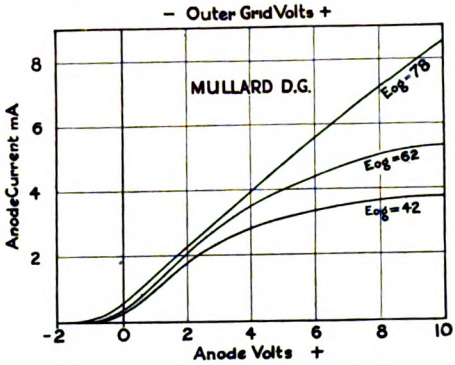
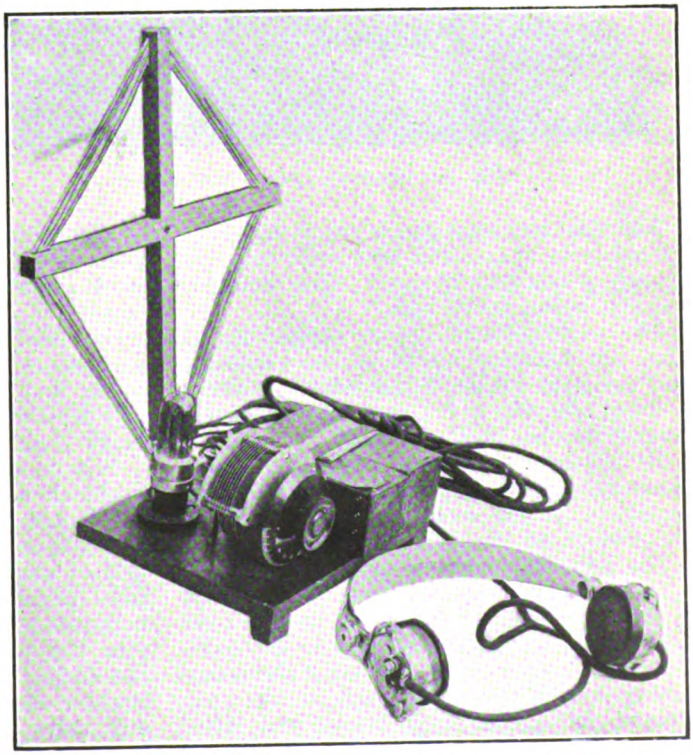


Fig. 7.

constants found from these curves are $\mu=6$, $R_a=30\,000$.

Lastly, the anode circuit, tested for rectification, gave the curves of Fig. 7, showing quite good results at about $-\frac{1}{2}$V.

Price, 27s. 6d.



A "High-tensionless" Receiver: range 20 yards on 5XX! It is used at Chelmsford as a test set.

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A Compact High-power "Super-Het." [R343

THE accompanying photographs show an attempt to build a portable nine-valve super-heterodyne.

The objects aimed at were, first, to condense a nine-valve set into small compass and second, to make it as simple as possible to "deliver the goods."

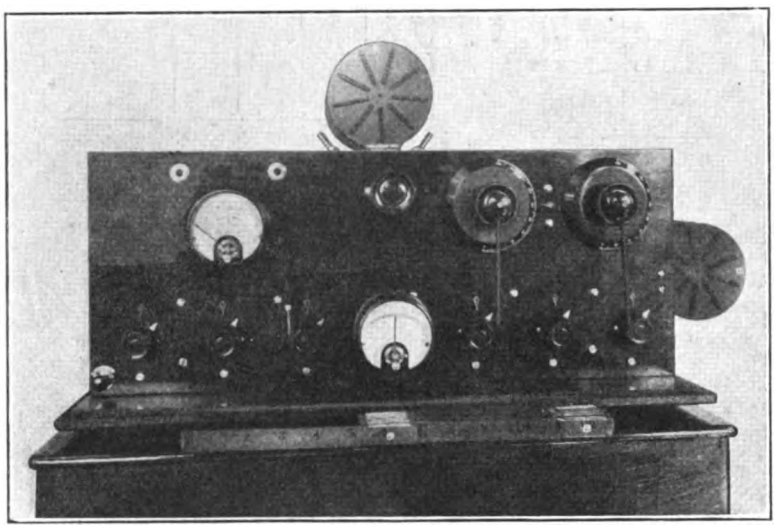

Fig. 1. *General Appearance of the Set.*

The front and back panels are 20 in. × 8 in., spaced 9 in. apart, and with coils removed fit into a box 21 × 13 × 9 in., thus fulfilling the first object fairly well.

The second I achieved by suppressing all H.F. amplification ahead of the oscillator, and using the tuning design which, so far as I know, was first given to the public in the August number of *Radio News*.

It consists essentially in applying the incoming signal, through a small fixed condenser, to the centre or nodal point of the grid-coil of the oscillator.*

The remarkable feature of this "hook up" is that all tuning can be done on either one of the two variable condensers, though I get better results by using the one in the oscillator circuit: the other, across the secondary tuning coil, being set and left almost anywhere. My procedure is to set the latter at 50 on the dial and tune in with the former.

I have even removed the ·0005 variable and replaced it with a fixed condenser of ·0001 with equally good results.

Once the rheostats and potentiometers are properly adjusted all stations between, say 300 and 500 metres wave-length (depending on the coils used), can be brought in by the manipulation of one dial. All other supers which I have ever seen built or on paper require the simultaneous adjustment of at least two condensers.

The diagram shows several departures from general practice. In the first place I have suppressed grid-leaks in the oscillator and detector circuits, after experiment, and find better all-round results are obtained by working on the lower bend of the characteristic with the assistance of a potentiometer.

The plate-voltage on all valves is the same: 100 volts.

The intermediate H.F. amplification consists of 4 iron-cored transformers, built to work around 30 K.C. (10 000 metres), preceded by an input transformer made up of 2 Gambrell coils, both tuned to 10 000 metres wave-length by condensers.

The first L.F. stage is followed by a stage of Push-Pull, though the latter is practically never required.

I have found a condenser and variable grid-leak across the secondary of the first L.F. stage of considerable advantage.

A Weston voltmeter, reading 15 on either side of zero, is shown in the centre of the front panel; and under each rheostat and potentiometer a small switch-point connected into the proper circuit. Contact between the end of the flex and one of the points enables one to read the filament-voltage of any valve, or how much negative-bias the potentiometer is putting on the grid—an unnecessary refinement, perhaps, but one which

*Query: is this really a nodal point?—Ed. E.W. & W.E.

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increases one's knowledge of the behaviour of valves in various parts of the circuit.

Another refinement shown is the milliammeter, connected in the plate circuit of the oscillator valve — at least it shows whether the oscillator valve *is* oscillating.

No switches have been allowed anywhere near an H.F. circuit; and on the L.F. side jacks have taken their place. The writer has always looked upon a switch as a trap to catch elusive electrons.

No comprehensive list of the components used has been given; the same results could be obtained with different parts, provided they are the best obtainable: that is a *sine qua non*. Another important point is to take the characteristic of every valve before use, and pick out well-matched ones for the intermediate H.F. and Push-Pull stages.

As to results, I cannot speak from great experience, as the set has only been built a short time. So far English, Dutch, German, French and Spanish stations have been tuned in on the loud-speaker—Radiola and some of the home stations with both aerial and ground disconnected: the chief charm of the set being to my mind the use of one condenser only when operating.

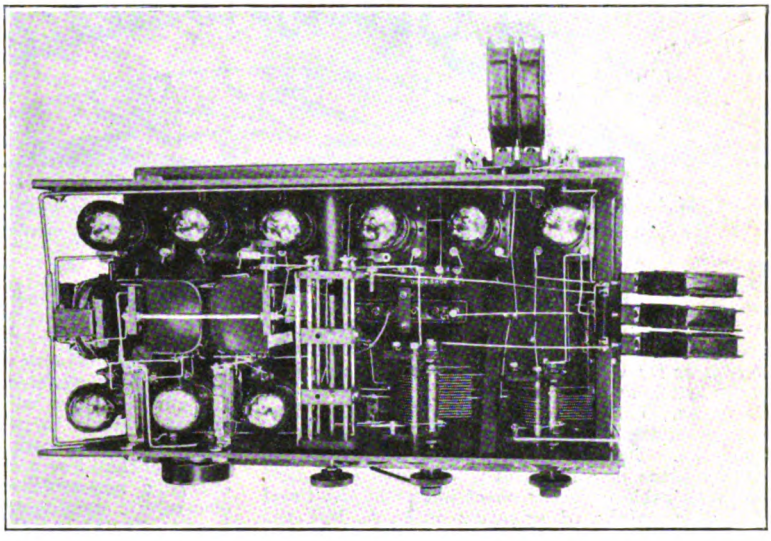

Fig. 2. *Uncovered View, showing the Construction.*

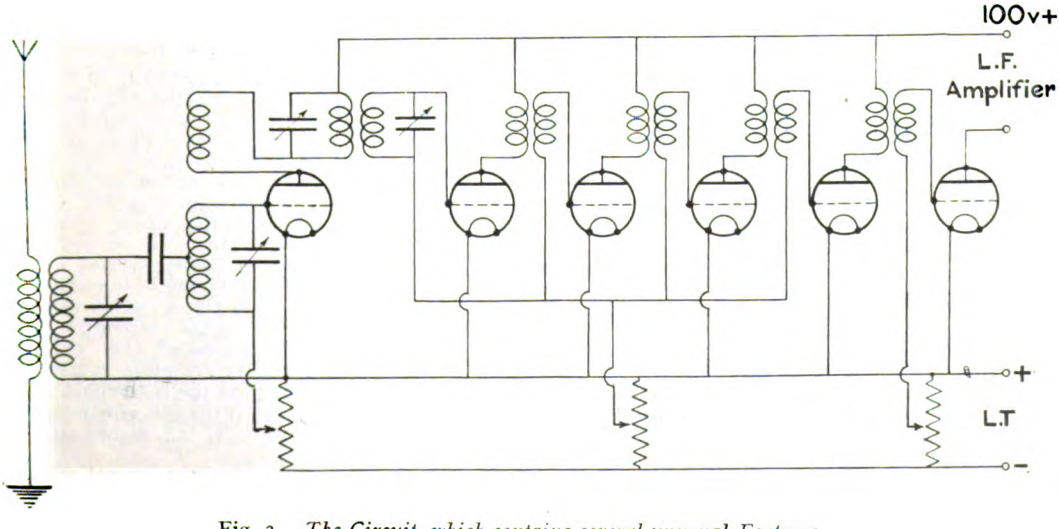

Fig. 3. *The Circuit, which contains several unusual Features.*

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Letters of interest to experimenters are always welcome. In publishing such communications the Editors do not necessarily endorse any technical or general statements which they may contain.

Electrolytic Rectifiers.

The Editor, E.W. & W.E.

SIR,—I read with great interest the communications from Dr. Corret and M. de Bruyne occasioned by my article in the August issue of EXPERIMENTAL WIRELESS. I have read the paper of Gunther-Schulze and Alberti referred to by these correspondents. The fact that fused salts may be used in place of an aqueous electrolyte and that the undesirable capacity effect is less in the fused salts is certainly of scientific interest, but the practical application of this fact presents obvious difficulties.

I have considered the subject chiefly from the point of view of the wireless experimenter who may desire to rectify a high-periodicity, high-voltage supply for a valve transmitter. Many amateurs complain about the messiness of the usual high-tension electrolytic rectifier, and I think that the limit of indulgence would be passed if we asked them to use fused potassium nitrate in each cell. The idea would be more acceptable if a maximum voltage of 500 or so were obtainable per cell; one could reasonably use one or two cells arranged compactly to be heated over one Bunsen burner or gas ring. But Gunther-Schulze and Alberti state definitely that the maximum voltage is only 90 for a cell employing fused potassium nitrate, which is no greater than for an aqueous solution of ammonium phosphate. Further research along these lines might, however, lead to practical results. For instance, it might be possible to use a eutectic mixture of two or more different salts with a very low melting-point.

With regard to the probability of the action of the electrolytic rectifier being an electronic phenomenon as against ionic, I am not prepared to contradict anyone who has conducted precise work on this point. Gunther-Schulze and Alberti only conclude that it is probable at the high frequencies at which they worked, and they do not state in what manner they expect the action to be wholly electronic.

Dr. Corret's remarks about the use of borax rather confirm my own experience. My original condemnation of borax was based on repeated experiments both with the commercial quality of salt and the pure salt obtained from a reputable firm of chemical dealers. Recently I bought some more pure borax from the same firm and gave it another trial in my high-tension rectifier. This time the results were quite good; the rectifier stood full voltage perfectly well and the aluminium plates kept in quite good condition. The only disadvantage was that the rectifier seemed to have a high impedance which increased with time, and it was difficult to get sufficient current through. Borax seems to work much better in high voltage rectifiers than low voltage ones such as are used for charging accumulators. Borax is excellent for electrolytic condensers, but for rectifiers of any kind I still maintain that pure ammonium phosphate is much superior and more reliable. With regard to the "20 Mule Team" borax so frequently referred to in American journals, this has puzzled me for a long time. It is typical of the unscientific method of the typical "ham" that he should inquire into the nature of what he is using no further than its irrelevant trade name.

London. E. H. ROBINSON.

Effective Transmission.

The Editor, E.W. & W.E.

SIR, — *Re* Mr. Hugh N. Ryan's article on "Effective Transmission," in the October issue of E.W. & W.E., I myself have been experimenting on the ratio of aerial current to signal strength, on a wave-length of 120 metres, and the reports I have received confirm the statement made by Mr. Ryan, "that an increase in aerial current does not always increase the signal strength." Mr. Corsham (2UV) and Mr. S. K. Lewer (6LJ) acted as report stations. As the aerial current was increased the signal strength increased up to a certain value, then as the aerial current was increased further the signal strength either remained constant or decreased. On the face of these reports the results are quite contrary to what one would expect from the theoretical standpoint; for instance, consider the following report:—

Aerial current at 5BH ·2A, signal strength at 2UV, R4.

Aerial current at 5BH ·4A, signal strength at 2UV, R3.

One would expect an increase of signal strength of about four times with the point four aerial current over the point two, in view of the fact that the power radiated varies as the square of the

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RMS value of the aerial current, measured at the base of the aerial.

It should be pointed out that the wave-length was kept constant during these tests, otherwise the reports would be of no value.

Mr. Ryan mentions a station "5CX" of Colne, this station is very near to mine. He reports that the signal strength fell away as the aerial current was increased. Would Mr. Ryan kindly inform me if the wave-length was kept constant throughout the test, also if he has noticed the effect from any more stations? Information on this point would be welcome.

One more point before concluding. Have any readers given any thought to this effect, that is, "change of note with wave-length," it being very noticeable on stations using direct current for H.T. supply? On some wave-lengths their note is pure CW, on others a harsh hissing sound. Why is this so? Any readers having views on this point might communicate with me at my address, or through this paper.

ALEX. V. SIMPSON, A.M.I.R.E. (5BH).

28, Westgate,
Burnley,
Lancashire.

L.T. Discharge Tubes.

The Editor, E.W. & W.E.

SIR,—The following notes, in the light of further work on the "Osglim" lamp and low-tension discharge tubes, may prove of use in supplementing the article by Clarkson and myself on "A Neon Lamp Method for the Comparing of Capacities and High Resistances."

It is stated there that "time periods greater than 2 to 3 seconds are not recommended, as it is our experience that they give inconsistent results." This inconsistency is, of course, due to the "lag" of the discharge behind the voltage producing it, and may be overcome by having a bright light, radio-active substance, or another continuously-running neon lamp, in the vicinity of the experimental tube. One of the last two agents is recommended, since no appreciable temperature effects are involved, such as might disturb the conditions of experiment; nevertheless sufficient ionisation in the "flashing" tube is provided to overcome the "lag."

The linearity of the "flashing" relations depends upon the equation,

$$T = CR\log_{\epsilon}\frac{E-V_c}{E-V_b} + C\Delta,$$

(see Taylor and Clarkson, *Journ. Scien. Instrs.* Vol. 1, No. 6, p. 751) where T is the total time period, C is the value of the capacity across the tube terminals (in microfarads), R is the resistance in the circuit (in megohms), E is the charging voltage of the battery employed, V_b and V_c are the lower and upper critical voltages respectively (see E.W. & W.E., Vol. 11, No. 13, p. 41), and Δ is approximately a constant.

It will be evident, that the accuracy of possible measurement of C and R depends upon the constancy of V_b and V_c, with C and R.

In some recent work (not yet published), in collaboration with W. Stephenson of Armstrong College, we have found, in the case of all the "Osglim" lamps investigated (including many of different patterns), that V_b decreases almost linearly with C from the highest capacities used (about 8 microfarads), down to 0·5 or 0·25 (according to the type of lamp used), but the graph slope is very small, there being a difference of a few volts only in some 130 or so over the whole range. Further, for these capacities, V_b is independent of E, the charging voltage, over a wide range, and of the external ionising agent.

For smaller capacities V_b decreases more and more rapidly, until with very small capacities of the order of 10^{-2} microfarads or so, it attains a minimum value, and probably increases with further diminution of C. V_b is consequently sufficiently steady in value to ensure that the results for C and R measurement, by the method of interpolation, are quite reliable. It would further appear from our results that V_c is, within the limits of experimental error, constant and independent of the nature of the external ionising source.

Newcastle-upon-Tyne. JAMES TAYLOR.

H.F. & L.F. Amplification.

The Editor, E.W. & W.E.

SIR,—With reference to Mr. Hogg's letter concerning my article on "The Use of Low-frequency Amplification for Long Distance Reception," I cannot see why he is disappointed that I should choose L.F. in place of H.F. Would he have me use H.F. because it should give better results from the theoretical point of view? The results I have obtained are in every way satisfactory.

H.F. amplification may be possible on the very short waves, but is the use of such methods justified by the increase (?) in range or signal strength? A supersonic-heterodyne (which may be termed a "brute-force" H.F. amplifier) will certainly give good range and audibility, but in the general opinion it is ruled out because of the very high ratio of cost of manufacture and maintenance to efficiency, *i.e.*, the very poor overall efficiency. When the number of H.F. amplifiers is reduced to one it becomes much less efficient—the overall efficiency is extremely small—and it is doubtful whether the results obtained with one H.F. and detector are any better than those obtained with a single valve.

Mention was made in your Editorial Views of the similarity of selectivity and "extra difficulty in tuning," which occurred in my table. The extra difficulty in tuning comes directly from the increased number of adjustments. It is generally understood that short-wave H.F. amplifiers are tuned. This means that there are three adjustments to make—the tuning of the aerial circuit, the tuning of the H.F. anode circuit, and the reaction coupling. The last named is extremely important—some people don't think so, but let them try it and see—the susceptibility of the receiver to really weak signals is increased enormously when it is only just oscillating. Any person whose DX reception is good will agree to this. Unless the operator is lucky enough to have three hands, something has got to suffer—it is the efficiency. A set which is hard to tune need not be selective; and a selective set is not necessarily hard to tune.

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Apparently Mr. Hogg thinks that selectivity is an advantage when searching for weak signals, and advises the use of a much smaller tuning condenser with a fine adjustment. Now, how can anybody search rapidly for weak signals over a large band of wave-lengths with a vernier condenser complete with a fine adjustment of one in umpteen thousands? It is utterly impossible. Therefore selectivity becomes a disadvantage.

Mr. Hogg is probably looking at H.F. and L.F. from the theoretical point of view. In dealing with the use of L.F. for DX work we are dealing with the practical side. What is the DX record of an H.F.-and-detector set compared with that of even a single valve? It is hopelessly in the background.

Perhaps a few notes on my results would be of interest to Mr. Hogg and others. Since writing the article in question the total number of Yanks I have heard has risen to 715. They were comfortably audible on a single valve right through the summer. On the 12th October, I logged 92 of them on one valve only while listening on a wave-band of 5 metres, and through interference from a transmitter, 200 yards away, putting 4½ amps into the aerial on that wave. The list included amateurs in all of the nine districts. WGY, on the 104 metre wave, came in comfortably on a single valve while the aerial and earth were disconnected, the former being lowered to the ground to eliminate re-radiation. Incidentally, about 9.30 one evening during the early summer I logged the call SQ from JMJK, followed by lingo which makes one wonder whether one has forgotten the code. Presumably, the station was in Japan, judging by appearance of the call-sign. I am awaiting confirmation. But that is by the way.

I have received confirmation of my reception from six Pacific Coast amateur stations. CB8 was received R6 on a single valve in a non-oscillating condition—simply by reading the beat note caused by a local heterodyning receiver also receiving CB8.

If these things can be done on one valve, why use an H.F. amplifier? It means another valve and another knob, to say the least; and even then the results are no better. My receiver is open to Mr. Hogg's personal inspection, and I am willing to make a comparison of the two types if it is desired.

S. K. LEWER.

32, Gascony Avenue,
West Hampstead, N.W.6.

[Our correspondent seems to have missed the point of our comment, as also of Mr. Hogg's. Ed., E.W. & W.E.]

The Editor, E.W. & W.E.

SIR,—I am particularly interested in the discussion going on in E.W. & W.E. regarding the type of apparatus most useful for the reception of short waves.

I am convinced that the popular "Rectifier and single note magnifier" boosted by a large section of "Radio hot-gospellers" is a compromise brought about by their inability to make any receiver which incorporates high frequency amplification function properly. The first mentioned receiver also appeals to the great majority of alleged experimenters, as it is tolerably immune from the effects of "spaghetti" wiring and the like.

As stated by some of your correspondents, H.F. amplification is of real use up to three million cycles and more, but if people use even efficient reactances tuned by armour-plated condensers (by the way, *who* invented variable condensers with metal end-plates?), and wired on the lines of the "shortest way is the quickest," it is no small wonder that they give up the investigation in disgust.

Personally, I do not use high frequency receivers for short waves in the ordinary sense, being a stanch upholder of the super-heterodyne, but I may say that the addition of a single H.F. stage previous to the first rectifier can be made of very real use in this type of receiver.

I also venture to suggest that in the case of the rectifier and note magnifier, there is a definite psychological effect of highly efficient loud reception just because there is a large amount of noise (signal, atmospheric and parasitic) emanating from the phones.

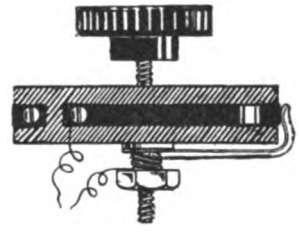
W. KENNETH ALFORD (2DX).

Rosedene,
Camberley, Surrey.

A Novel Grid-Leak.

The Editor, E.W. & W.E.

SIR,—The following hint may be of value to experimenters in wireless.



A piece of *passe-partout* makes an excellent grid-leak, and gives constant results. This material can be obtained from any good class stationers or photographic dealers at a very small cost.

I have a leak made up of dimensions indicated in the sketch. This I can vary from zero to 4 megohms, the material is three inches long by one-eighth inch wide, and is mounted as shown. I trust this will be of value to your readers.

C. W. H. BENNETT.

"Southcote,"
King Street,
Wokingham.

The Winter's Work Begins.

The Editor, E.W. & W.E.

SIR,—I beg to advise you of two-way working between American 1AAC—Framlingham, Conn., U.S.A. and G.2KF in the early hours of September 23rd. Contact was maintained for about one hour on short waves.

I believe this is the first two-way communication this autumn.

J. A. PARTRIDGE (G.2KF.)

22, Park Road,
Collier's Wood,
London, S.W.19.

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Work in S. Africa.

The Editor, E.W. & W.E.

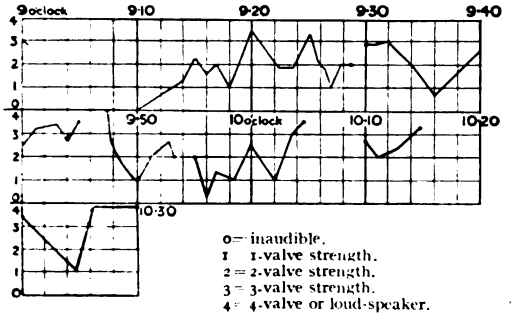
SIR,—In your August number I notice you have a request to readers asking them to inform you of the types of articles that interest them.

I suppose you have a number of readers in this country who are keen experimenters, like myself. We are handicapped in the one sense that a transmitting licence only allows one to transmit for a radius of five miles, although there are a number of amateurs broadcasting on 200λ some of whom are heard 600-700 miles away. I do not understand how they keep within the regulations

Transmission, therefore, interests us more from the theoretical point of view.

The distances out here being so great compared with the old country, most of our experiments are carried out with a view to obtaining clear reception at a distance of, say, 500 or 600 miles from the broadcasting station. The set must not be too large, must be practically dustproof, and be economical in working; for battery charging costs 12s. 6d. a time in this town.

A set as described in your last issue, or, rather, a circuit for a three-valve set, which the author says gives loud-speaker results at five miles from 2LO, is of little use to us. There is, of course, much satisfaction to oneself on reading that article knowing one gets loud-speaker results on a four-valve set of home manufacture 500 miles from J.B.



Long-distance reception over the earth's surface has problems of its own. Take, for example, fading, one of the bugbears apparently little is known about. Some nights fading is very pronounced from loud-speaker strength to inaudibility in, say, two minutes.

I put it down to a more or less run-down L.T. battery, but have noticed it on a battery up to full strength. I am enclosing a rough chart taken one Sunday night which gives some idea.

Next month extensive experiments are being carried out in this country both by *Radio*, our South African magazine, on the Lourenço Marques time signal and also by the Johannesburg Broadcasting Company.

The results of these should be interesting and instructive provided data, such as nature of country, etc., is noted as well.

Our other bugbear is atmospherics. On August 19, for instance, these were so bad and so continuous as completely to blot out all signals, morse as well as telephony. As atmospherics are aperiodic I do not see how they can be eliminated. They are as bad on 200 metres as 600, culminating at their worst, curiously enough, at 450, which is J.B.'s wave-length.

We are also very worried by interference from shipping. Lourenço Marques sometimes nearly blots out the telephony from J.B., and the former is a hundred miles farther away. If the tuning for the commercial stations was as fine as for telephony we should have no difficulty, so an article on interference eliminaters, theory, practical construction, etc., would be appreciated; the author remembering that some of us have no reference library within 100 miles and no one to go and discuss things with.

To sum up, the subjects from a practical point of view useful to us out here, are long-distance reception, elimination of interference, and the subjects of fading and atmospherics.

GEO. K. MALLORY.

P.O. Box 22,
Cathcart, C.P.,
South Africa.

A Reader's Wishes.

The Editor, E.W. & W.E.

SIR,—Congratulations on your journal. The paper, printing, photos, and especially the fact that the advertisements are kept separate, are quite what one could expect when looking forward to the binding of such a volume from the purchaser's point of view. The arrangement is ideal.

The articles, too, are of such a variety as to give everyone some article of interest dealt with in a substantial way by experts.

I was much interested in the article on the "Old Vic" Relay. Will you please give articles from time to time on valve transmitters using "Master Oscillator" and other systems, with diagrams and photographs of the sets used? Could you give us some photographs of the apparatus used by the B.B.C. for transmitting (not the 2LO microphone)?

Being a commercial radio "fan" I appreciated article on p. 224 and that on the Devizes Station and manufacture of valves. Page 387 was also interesting and the two articles on selectivity in No. 7.

I am looking forward to receiving some more issues from home. Trusting your journal will have the wide circulation it merits, and wishing you every success, I remain,

"ANTENNA."

[This letter is dated many months ago.—Ed., E.W. & W.E.].

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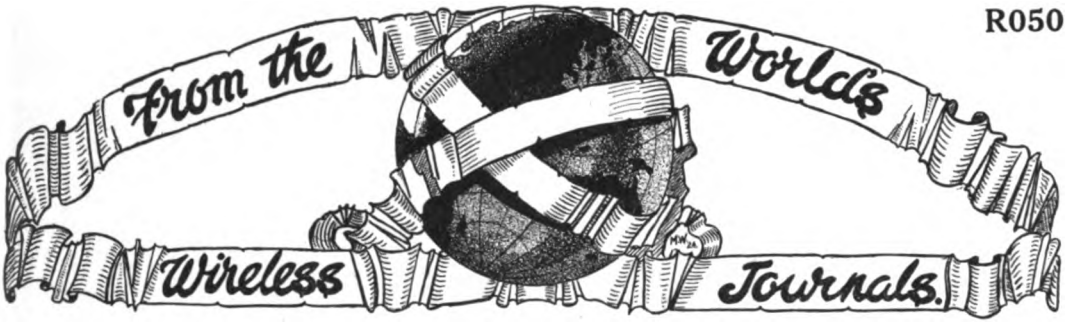

R050

R000.—GENERAL.

R025·4.—The Arrangement of Wireless Books and Information.—(*Exp. W.*, Oct.).

Explanation of Dewey system of classification and the Bureau of Standards extension of it, with special reference to its application to press cuttings, books, papers, etc., referring to wireless matters.

R100.—GENERAL PRINCIPLES AND THEORY.

R110.—Some Experiments Confirming the New Theory.—Prof. G. W. O. Howe, D.Sc. (*Electn.*, Oct. 10.)

Prof. Howe gives some experimental data derived from measurements made on the signal strength of Nantes by the vessel *Aldébaran*; these experiments in some measure confirm Prof. Howe's new theory of the propagation of radio waves over long terrestrial distances.

R110.—Portée des Ondes; Action de l'Atmospère.—M. J. Guinchant (*Onde Elec.*, Sept.).

Discussion on the various attenuation formulæ that have been put forward. It is shown that the purely theoretical formula of Watson always predicts weaker field strengths at a distance than the empirical formula of Austin does; whereas the older Hertz-Blondel formula indicates larger values than the Austin formula. The writer states that if the Hertz-Blondel formula is corrected for the effects of the atmospheric medium then the modified Hertz-Blondel values come into closer agreement with observed values.

R110.—Etude sur les Irrégularités de Propagation des Ondes Courtes.—P. Lardry (*Onde Elec.*, Sept.).

Some experiments on the intensity of signals on short waves. Variations in intensity were too rapid to allow measurement of field strength so that the shunted-telephone method of measuring audibility was used. The data obtained are represented by a number of curves. Measurements over an extended period were taken during the day under various weather conditions.

R113.—Effective Transmission.—H. N. Ryan (*Exp. W.*, Oct.).

Some notes on points which count in operating a valve transmitter to produce effective signals at a distance.

R149.—Valve *v.* Crystal for Detection.—P. K. Turner (*Exp. W.*, Oct.).

The *modus operandi* of the valve and crystal rectifier is summarised and the two are compared for distortion effects, much to the disadvantage of the valve, which latter cannot fail to give distortion on telephony when the grid-condenser and leak method is used.

R200.—MEASUREMENTS AND STANDARDISATION.

R240.—High-Frequency Resistance.—J. H. Reyner, B.Sc. (*Exp. W.*, Oct.).

Description of a simple method of testing coils for high-frequency losses.

R260.—The Vacuum Tube Voltmeter.—J. H. Turnbull (*Q.S.T.*, Oct.).

A method employing a three-electrode valve to measure high voltages at any frequency.

R300.—APPARATUS AND EQUIPMENT.

R320.—Transmission Experiments at 8AQO.—S. Kruse (*Q.S.T.*, Oct.).

Second part of a description of experiments to determine relative merits of earth and counterpoise on various wave-lengths as indicated by field strength measurements at a short distance from the transmitting station.

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R342.701.—THE PERFORMANCE AND PROPERTIES OF TELEPHONIC FREQUENCY INTERVALVE TRANSFORMERS.—D. W. Dye, B.Sc. (*Exp. W.*, Oct.).

Second instalment of a paper on some original research work on the impedance of intervalve transformer windings and the general electrical properties of these transformers. This is perhaps the most complete investigation of the subject that has been yet undertaken.

R343.—COMMENT J'AI REÇU OC9.—Capt. Ancelme (*Onde Elec.*, Sept.).

Practical description of a receiver for wavelengths of 9 metres.

R343.—A STUDY OF SUPERHETERODYNE AMPLIFICATION.—H. A. Snow (*Q.S.T.*, Oct.).

Some considerations of the conditions governing the operation of supersonic heterodyne receivers.

R344.—WORKING AT 5 METRES.—S. Kruse (*Q.S.T.*, Oct.).

Some practical circuits for short-wave transmitters; also methods of measuring these short waves.

R344.—A PROPOS DES ONDES COURTES.—P. Girardin (*R. Elec.*, Sept. 25).

Some notes on circuit arrangements for valve sets operating on wave-lengths of the order of two or three metres.

R344.—LOCAL OSCILLATION GENERATORS.—(*Electn.*, Oct. 10).

A description of recent patterns of Marconi local oscillators.

R350.—THE CRYSTAL AS A GENERATOR AND AMPLIFIER.—Victor Gabel (*W. World*, Oct. 1 and Oct. 8).

An English account of the work of the Russian engineer, O. Lossev on crystals as amplifiers and oscillators. A number of circuits are illustrated in which crystals are used for these purposes and a complete crystal regenerative receiver is described.

R350.—LES DÉTECTEURS GÉNÉRATEURS.—M. Vinogradow (*Onde Elec.*, Sept.).

An account in French of Lossev's work on oscillating crystals. The mathematical theory is dealt with, as well as the practical circuit arrangements.

R355.—A METHOD OF OBTAINING A.C. FOR TRANSMISSION.—J. K. Jennings, B.Sc. and B. L. Stephenson (*Exp. W.*, Oct.).

How a D.C. motor may be adapted to act as a rotary converter of D.C. to A.C.

R370.—THE PERFECT SET; PART I.: THE CRYSTAL SET.—P. K. Turner (*Exp. W.*, Oct.).

The first of a series of articles dealing with points of fundamental importance in the design and operation of receiving sets, which are frequently overlooked in constructional articles.

R381.—THE REMOTE CONTROL OF VARIABLE CONDENSERS.—Leonard A. Sayce, M.Sc. (*Exp. W.*, Oct.).

Short note on a method of actuating variable condensers at a distance.

R382.—THE RECEIVING COIL PROBLEM.—G. W. Pickard (*Q.S.T.*, Oct.).

The defects of spiderweb and cylindrical coils are discussed.

R400.—SYSTEMS OF WORKING.

R410.—LE CODE DU GÉNÉRAL O. SQUIER.—W. Sanders (*R. Elec.*, Sept. 10).

A description of Squier's morse system in which dots and dashes have same duration but different amplitudes.

R800.—NON-RADIO SUBJECTS.

STUDIES OF ELECTRIC DISCHARGES IN GASES AT LOW PRESSURES.—Irving Langmuir and H. Mott-Smith (*Gen. El. Rev.*, July, Aug. and Sept.).

Series of articles on the phenomena of gaseous discharges in low-pressure discharge tubes such as mercury arc rectifiers, etc. The theory of plane, cylindrical and spherical collectors, with retarding and accelerating fields, is presented.

RECTIFIER WAVE FORMS.—D. C. Prince (*Gen. El. Rev.*, Sept.).

A technical article dealing with the various factors influencing the wave form of the outputs of single and multiphase rectifiers.

POWER CIRCUIT INTERFERENCE WITH TELEGRAPHS AND TELEPHONES.—S. C. Bartholemew (*Journ. I.E.E.*, Oct.).

This paper deals mainly with interference with line work by power circuits, but the subject is of interest to the wireless worker under certain circumstances. The questions of harmonics in A.C. supplies, noises from D.C. supplies, electric railways, etc., are dealt with.

SOUND IN RELATION TO WIRELESS.—Prof. E. Mallet, M.Sc. (*W. World*, Sept. 17 and Sept. 24).

The composition of various sounds is considered and the presence of upper harmonics in everyday sounds is shown to be essential to their particular characteristics. Some interesting oscillographs of various sounds are given.

ON SOME PROPERTIES OF LOW-TENSION DISCHARGE TUBES.—J. Taylor, B.Sc. (*Exp. W.*, Oct.).

Article dealing with the volt-ampère characteristics of discharge tubes of the Neon, or "Osglim" type. The properties of these tubes as oscillators and rectifiers is described. The "short-path" principle used in certain types of rectifier is explained.

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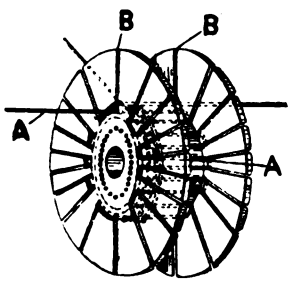
(The following notes are based on information supplied by Mr. Eric Potter Patent Agent, Lonsdale Chambers, 27, Chancery Lane, W.C.2.)

[R008

DURIC COILS.

(Application date, June 12, 1923.)

An extremely neat form of tuning coil is that described in respect of Patent No. 217,045 (J. D. Dunthorne, of Ladywell, and W. J. Rickets, of Brixton). In this coil consecutive layers of wire are separated by string in order to provide an air space between them. A former for use in constructing the coil is shown in the drawing.



The dotted lines show the disposition of the string and the beginning of a layer of wire, the turns of which should be preferably spaced.

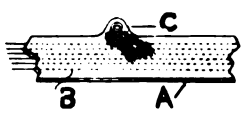
By tuning one disc in one direction to throw the slots in the discs out of alignment and adjusting its perforations over different pins in the core of the former, subsequently completing a layer of string and superimposed layer of wire, and then turning the disc in the opposite direction the string can be laid in layers disposed diagonally in opposite directions.

When the winding is completed the string loops on the outside of the former are cut and the discs removed. The coil is then treated with insulating varnish to make it rigid and the projecting ends of the string trimmed off.

LOOP AERIAL TO FIT WALLS OF ROOM.

(Convention date, January 11, 1923.)

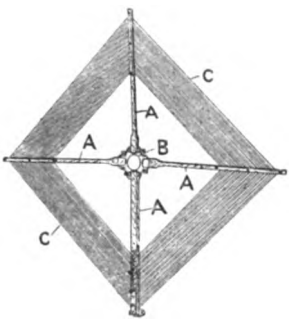
The figure illustrates A. N. Goldsmith's Patent No. 209,758. Instead of the ordinary small frame aerial a strip of flexible material A is used in which run a number of parallel wires B, sufficient length of this strip being used to run along walls, ceiling and floors to form a closed loop. The wires B are joined where the ends meet so as to constitute a large multi-turn inductive loop which can be used for the reception of radio signals. Tabs C may be provided to facilitate fixing the strip in position.



COLLAPSIBLE FRAME AERIAL.

(Application date, February 28, 1923.)

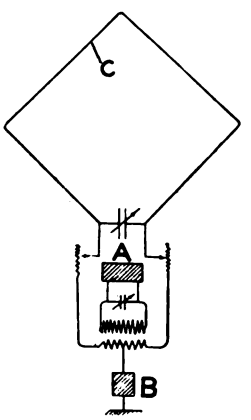
Certain features of the collapsible frame illustrated form the subject of Patent No. 216,578 of the British Thomson-Houston Co., Ltd., and R. C. Clinker. The arms A of the frame are pivoted at their junctions to the central boss B so that they can be folded together when the frame is out of use. The mounting of the arms is so arranged that they open out a little beyond the position where they are in the same plane when the tension of the wires C maintains them in this position. It is stated that when the frame is closed the wires show no tendency to get muddled, but hang in natural folds. A special tripod stand (not shown) for use with the frame is described in the specification, which is so constructed that the downward pressure of the frame due to its weight causes the vertical shaft to be gripped.



AERIAL SYSTEM FOR DUPLEX.

(Application date, June 25, 1923.)

An ingenious scheme for simultaneous transmission and reception on the same aerial forms the subject of Patent No. 217,060 of E. Boselli. An elevated loop C is used in such a manner that the receiver A utilises its frame-aerial properties while the transmitter B energises the loop as an ordinary open capacity aerial. Various means are described in the specification for balancing out interaction between transmitter and receiver.



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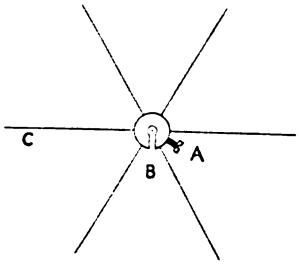
STATIC CHARGE ON AERIALS.

(*Application date, August* 4, 1923.)

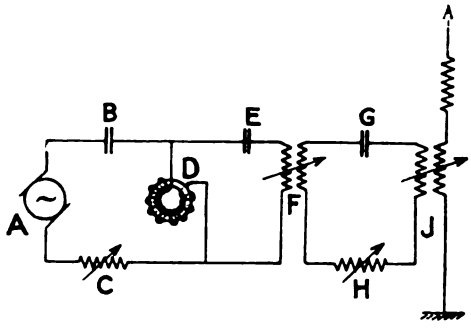


A boss B, adapted to be fixed on to an aerial wire by means of a set-screw A, carries a spike or number of spikes C, which act as discharging points to dissipate any electrostatic charge which may accumulate on the aerial. The patentee is Mr. C. H. Woodward, and the number of the patent 219,185.

ELIMINATION OF HARMONICS.

(*Convention date, November* 29, 1922.)

It is difficult to run transmitters at high efficiency without the radiation of harmonics. In Patent No. 207,781 W. Doring covers the use of an intermediate resonant circuit G F H J between the oscillation generator A and the aerial circuit to filter out undesired harmonic components. In the illustration A is the initial high-frequency generator



and D a frequency multiplier such as is common in long-wave high-power stations. Condenser E and transformer 6 form a system resonant to the desired frequency which serves to transfer the output of D at this frequency to the intermediate circuit and aerial system. We do not quite see where the novelty lies, however, in the mere use of an intermediate circuit.

UNITS FOR RECEIVING SETS.

(*Application date, August* 2, 1923.)

Patent No. 220,161 of Stockall, Marples & Co. covers a wireless set comprising a panel having two connectors and a filament resistance and being wired up so that any number of such panels can, by a mere interchange of plug-in units, be adapted for addition to a foundation panel so as to produce receiving sets of different nature at will. The foundation panel is adapted to be used by itself as a crystal set and is fitted with all the battery wires necessary for the addition of valves.

NEW DEPARTURE IN COATED FILAMENTS.

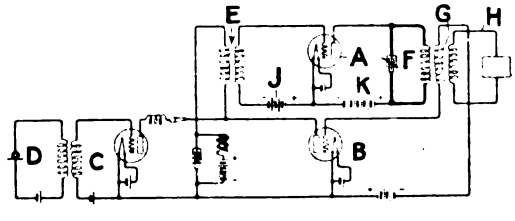
(*Application date, April* 25, 1923.)

Patent No. 219,396 of the Edison Swan Electric Co., Ltd., P. Freedman and E. Greetham covers the use of electron-emitting coatings such as lime, thoria, etc., not in actual contact with the filament itself but as a narrow tube surrounding the filament and free from any metallic supporting base. A method of preparing this non-integral coating or tube is described in the specification. The filament is coated electrolytically with a base metal such as copper; over this is coated electron-emitting substance and the copper is subsequently removed by electrolysis or other suitable means. How this coating remains supported the patentees do not say.

EFFICIENCY IN VALVE OSCILLATORS.

(*Convention Date, March* 31, 1923.)

It is impossible for an oscillating valve to give a pure sine wave at an efficiency greater than 50 per cent. Oscillations produced at higher efficiencies are more in the nature of series of impulsive kicks, there being only a comparatively small D.C. component of the space-current. From a practical point of view it is preferable to work with these high-efficiency but distorted oscillations, as the energy wasted in the valve itself is greatly reduced. A method of generating oscillations of this type has been patented by the Western Electric Co., Ltd., and H. W. Nichols (Patent No. 213,562) and is illustrated herewith. A is the main power valve



fed from a D.C. source K through the main oscillatory circuit F. By means of the bias battery J the grid of A is made so negative that A normally passes practically no current. Reaction coupling between input and output circuits of this valve is effected through the coil G and the H.F. transformer E. It will be noticed that this reaction circuit contains a relay valve B which acts as a "distorter" of the grid excitation of A in such a manner that the latter consists of high positive potential impulses of very short duration compared with the periodic time of the oscillations to be generated in the load-circuit H. Telephonic modulation may be effected by choke-controlling the distorter B with another valve C. The inventors state that with this system they can attain a higher efficiency than has been previously known.

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THORIATING TUNGSTEN FILAMENTS.

(*Application date, March* 19, 1923.)

In Patent No. 217,646, Dr. L. A. Levy covers a method of electrolytically thoriating tungsten wires for use as low-temperature electron-emitting filaments. The tungsten wire is made cathode in a cell containing a solution of a thorium salt as electrolyte. The chloride or perchlorate may be used. The wire may be passed through the solution continuously, each part being submerged for about half a minute.

THE GRIMES DUAL CIRCUIT.

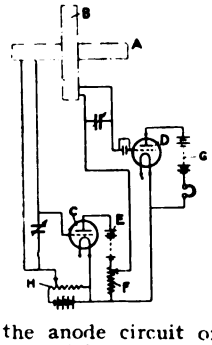
(*Convention date, September* 19, 1922.)

D. Grimes of America has patented the well-known reflex circuit in which a number of valves act simultaneously as H.F. and L.F. amplifiers, the circuit being characterised by the fact that the valves are made to act as L.F. amplifiers in an order different from that in which they act as H.F. amplifiers. Thus the last H.F. valve is made the first L.F., while the first H.F. valve functions as the final L.F. stage. The object is to keep the load on the various valves as uniform as possible. (Patent No. 204,301.)

D.F. RECEIVER.

(*Application date, May* 1, 1923.)

The diagram illustrates a directional receiving scheme covered by Patent No. 220,029 of Dr. J. Robinson and G. J. R. Joyce.



Two frame aerials, A and B, are fixed at right-angles with respect to each other and rotate together about a vertical axis. The detecting valve D is associated with frame B. Frame A is connected to another valve C whose function is to paralyse the detector D except when frame A is at minimum with respect to the station being received. In order to effect this a resistance F is connected in series with the battery E in the anode circuit of the valve C. The positive potential derived across part of this resistance F is applied to the grid of D. The grid of C is biased negatively by means of H so that the arrival of signals in A increase the conductivity of the valve C and hence the positive potential applied to the grid of D by the resistance F. Since this positive potential will always exist to a greater or less extent, except when there are no signal currents in A, it follows that the detector will be sensitive only when A is in the minimum position and B in the maximum position.

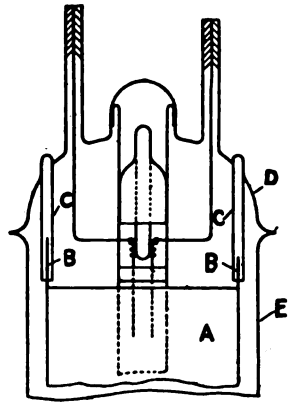
APPLYING COATINGS TO FILAMENTS.

(*Convention date, January* 12, 1923.)

Patent No. 209,730, held by the Dutch firm of Philips, covers a process of applying alkaline earths to electron-emitting cathodes in such a way as to be firmly adhesive. The body to be coated has at least its surface covered with some metal which will form an alloy with the alkaline earth metals. A layer of alkaline earth metal is applied to this surface and the whole is heated in a reducing atmosphere to allow the alloying action to take place. The body thus coated is then heated in an oxidising atmosphere so that a layer of the alkaline earth oxide is formed at the surface.

VALVE CONSTRUCTION.

(*Application date, March* 1, 1923.)

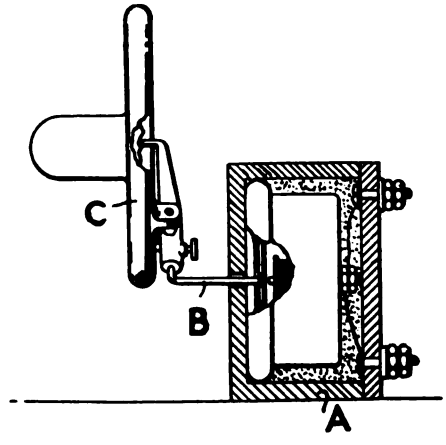


Patent No. 216,585 of C. Seymour, H. G. Hughes and T. E. Goldup deals with the construction of power valves of certain types in a manner to facilitate assembly. The anode supporting wires B are made of unequal length in order to facilitate their fitting into the supporting tubes C when the cap D of the envelope is being fitted to the main body E.

GRAMOPHONE AS LOUD-SPEAKER.

(*Convention date, April* 5, 1923.)

The diaphragm of a telephone receiver A is connected through a member B to the needle holder of



a gramophone sound-box C. Thus telephonic vibrations produced in A are reproduced in the gramophone system. (Patent No. 213,936, R. E. B. Wakefield.)

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EXPERIMENTAL WIRELESS & The WIRELESS ENGINEER

VOL. II. DECEMBER, 1924. No. 15.

Editorial Views.

H.F. & L.F.

THE discussion on the choice of L.F. or H.F. amplification for short wave long distance reception has been getting almost acrimonious. But perhaps a discovery of our own may cast oil on the troubled waters. A chance remark in one of the letters gave us the clue, and the great discovery is this: that the opponents are working at cross purposes the whole time! They are sitting down to their sets with quite different ideas of what they want, and naturally they have specialised in sets that suit them.

Mr. Lewer, the originator of the "ruction," is beyond everything interested in logging stations, *i.e.*, getting the maximum number of call signals down. Naturally he wants a set tunable with the greatest ease. Mr. Hogg, on the other hand, specialises in actual communication—two-way working. He wants to get in touch with a given station in Mars or elsewhere, and work it steadily. Naturally he is not so anxious to swing all over the wave-length range every ten seconds; but he wants selectivity and good signals to avoid repetition, so he plumps for an H.F. stage.

The real lesson to be drawn is—the danger of hasty generalisation. It is unsafe to assume that the set which suits *us* best is really the *best* set for everybody.

The Square-law Fallacy.

There is a rage just now for square-law condensers. How many of our readers, we wonder, realise that in practice the square-law condenser does *not* give a "straight-line" curve of wave-length against degrees? In making this statement we are not referring only to bad condensers, with vanes that are not cut to the accurate "square-law" curve; but to good ones also. The reason is a simple one; in no case, as far as we know, is allowance made for the zero or stray capacity. Take a numerical example. Suppose a condenser of 1 000$\mu\mu$F maximum. In a square-law condenser the condenser is designed to give 250$\mu\mu$F at 90°, while the ordinary type gives 500$\mu\mu$F at this angle. Both, as far as design is concerned, are supposed to have zero capacity at 0°. But actually we must add say 30$\mu\mu$F for stray capacity, and this throws the whole scale out.

As it happens, the effect is much more serious on the square-law condenser. The straight-line condenser still gives a straight line curve of capacity, whatever the "stray." But the square-law, which is supposed to give a straight line curve of wave-length, does not do so if there is stray capacity.

Even if the vanes were cut to a different shape, to give a straight-line law after allowing for the zero capacity, it will still be upset when the condenser is put into use, for allowance must be made for the self-capacity of the coil and the rest of the circuit.

Lest we be accused of hair-splitting, we might mention that in four wave-meters recently calibrated (provided with square-law condensers) the calibration curves were nothing like straight lines.

Do we want the Square-law?

But supposing that we did get a condenser adjusted to give a square-law on a given circuit, is it what we want?

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After all, the idea of using a square law is to avoid the difficulty that an ordinary condenser is too sensitive at low angles, *i.e.*, there is too large a change in wave-length for a given movement. In the perfect square-law type, the change of wave, in meters, will be constant for a given movement. But this is not quite right. A change of five metres at 50 metres will affect signal strength as much as one of ten metres at 100 metres. What we really want is that a given movement shall give a constant *percentage* change of wave-length. For this neither the ordinary nor the square-law condenser will do; but plenty such condensers have been made, especially for decremeter work. In fact, the Americans usually refer to these condensers by the name of Kolster, who used them in the standard Kolster Decremeter.

Circuit Calculations.

The article in our last month's issue, on calculating A.C. circuits, appears to have attracted considerable interest. In a sense, Mr. Colebrook's article this month, on the Graphical Analysis of Composite Impedances, is a continuation of it, although it was written before our article.

It appears, however, that further simple explanation is needed on certain points—one reader is quite disinclined to do as we requested, and take our word for it that a condenser carries a leading current—and so we propose to give (probably next month) a further article, dealing with sine-waves, amplitude, phase, vectors and such-like mysteries.

The White City Show.

A rapid inspection of the White City Exhibition—all that we had time for before going to press—showed that although it opened with little ostentation, and did not occupy a very large space, there was an astonishing amount of novel and useful stuff for the amateur. There was not very much in the way of expensive cabinet sets to tempt the plutocrat—though the few such sets shown were very fine—but the components and accessories that we depend on were present in full force.

Crystals.

We have in hand quite a large batch of crystals for test, which would normally have been reported this month.

But we have always realised that our method of testing crystals (though better, we believe, than most methods commonly adopted) has been not entirely satisfactory, and the only thing that has prevented us from adopting a different method has been the difficulty, first of finding the correct method and second, of applying it.

The problem is, in fact, an exceedingly complex one. It is obviously desirable to apply a known H.F. voltage, and measure the resulting D.C. output. But the matter is complicated by the fact that to get the best out of the crystal one must try it with a large number of different loads in the output, and that the change of output load affects the power taken. As a result, it would take two or three hours to test a single point on a single sample.

We have therefore decided on a compromise. We propose to report the performance of a crystal *under normal conditions, i.e.*, with a load corresponding to that of an ordinary pair of phones. Preparations for such testing are now under way, but a surprising amount of work is required. The problem involves measuring radio-frequency voltages from about ·1 volt up to 1 volt, and currents of a few milliamps, as well as D.C. currents of a few microamps. This in turn necessitates the calibration of a delicate thermo-junction, the making and calibration of a Moullin voltmeter, and the construction of a stable H.F. oscillator. Certainly none of these tasks are very difficult, but they consume a good deal of time. We hope next month to have some results.

Calibration.

We regret that, although we have cleared off all wavemeter calibrations and almost all other calibration work, the checking of our instruments is not yet complete, so that we are not yet ready to receive apparatus again, except as regards the measurement of resistance and the checking of ammeters and voltmeters, which we can do.

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The Arrangement of Wireless Books and Information. [025·4

Part III: R200—Measurements and Standards.

Continuing our list of reference numbers for the filing of wireless information, we now deal with the important subject of measurement. For the first time we find what appears a flaw in the B.S. extension, and in spite of our desire to adhere to an existing classification, we feel impelled to suggest a slight change, as will be seen below.

R200 Measurements and Standards.

The scope of this section is clearly indicated by its title, and no further explanation appears necessary.

R201 General methods and apparatus.

In the B.S. extension, various headings are given under 201 to 205, as follows:—

R201·2	*Use of valves.*
·5	*Shielding and earthing.*
·6	*Bridge methods.*
·7	*Oscillographs.*
R202	*Resonance methods.*
R203	*Harmonics.*
R204	*Null methods.*
R205	*Substitution methods.*

It appears to us, however, that this subdivision might cause much confusion by clashing with the general "form divisions," which are supposed to be applicable to any number: *e.g.*, R201·5 is given above as "shielding." But on the form division (see E.W. & W.E., October, 1924, p. 8) ·015 means "various theories," so 201·5 should mean "various theories on measurement."

We therefore, while giving the above numbers for completeness, suggest that they be not used, and propose to arrange similar entries in a way consistent with the "form division." R201 remains "General methods," as this is consistent. It will be noted that the divisions which follow fall in with those given under Rooo (E.W. & W.E., October, 1924, p. 8) but extend them somewhat. Further, this allows the "method" subdivision to be used for any type of test: *e.g.*, R201·21, Bridge methods; R220·121, Bridge methods for measuring capacity.

*R201·15	Formulæ.
*R201·2	Classification of methods.
* ·21	Null methods in general, including bridge tests.
* ·22	Resonance methods, including harmonics.
* ·23	Substitution methods.
*R208	Miscellaneous matters in measurement.
*R208·1	Calibration tables.
* ·2	Calibration charts.
* ·6	Standard generators for test work (special oscillators, etc.).
* ·7	Means of detection: general notes. For detecting current, voltage, etc., see below.
* ·8	Screening, earthing, and precision precautions generally.

*** These subdivisions are proposed by us as a tentative further extension.**

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R210 Frequency and wave-length.

R211 Resonance methods.
R213 Extending by harmonics.
*R217 Absolute measurements.
*R218 Standards.

R220 Capacity.

R223 Dielectric constant.

R225 Self-capacity of coils, etc.
*R227 Absolute measurements.
*R228 Standards.

Note that measurements of dielectric loss (or power factor or phase difference) are really measurements of resistance. (See R240.)

R230 Inductance.

R231 Self-inductance.
R235 Mutual inductance.
*R237 Absolute measurements.
*R238 Standards.

R240 Resistance, damping, etc.

*R245 Radiation resistance.
*R248 Standards.

R250 Current.

R251 Current measuring instruments (ammeters, etc.).
R251·1 Hot-wire ammeters.
·2 Thermo-junctions.
·3 Current transformers.
·4 Dynamometer type instruments.
·5 The Einthoven galvanometer and similar instruments.
·6 Bolometers.
*R257 Absolute measurements.
*R258 Standards

R260 Voltage.

R261 Valve voltmeters (Moullin, etc.).
R262 Spark-gap voltage measurers.
R263 Electrostatic voltmeters.
*R267 Absolute measurements.
*R268 Standards.
R269 Voltmeters not indicated above.

R270 Signal strength measurement.

R271 Shunted telephone and similar methods.
R272 Radio-frequency comparison methods.
R273 Audio-frequency comparison methods.
R275 Modulation measurements.

R280 Properties of materials.

R281 Insulating materials.

NOTE.—We have added the following subdivision to apply either to insulating materials as a whole or to any of them :—

*·012 Special properties.
*·012·1 Volume resistivity.
* ·2 Surface resistivity.
* ·3 Dielectric strength.
* ·4 Dielectric constant.
* ·5 Dielectric losses.
* ·6 Effect of temperature, humidity, etc.

* These subdivisions are proposed by us as a tentative further extension.

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R281·1	Laminated insulators (Bakelite, Fibre, etc.).
·11	Phenolic types (Bakelite, Condensite, etc.).
·13	Fibre.
·2	Moulding materials.
·31	Porcelain.
·33	Glass.
·35	Rubber and ebonite.
·37	Gutta-percha.
·38	Mica.
·383	Built-up mica compounds.
·41	Textile materials.
·42	Paper and cardboard.
·43	Wood.
·44	Waxes.
·45	Pitch.
·46	Paraffin wax.
·47	Varnishes.
·48	Shellac.
·49	Oils.
·6	Resins.
·61	Natural resins.
·62	Synthetic.
·7	Minerals, etc.
·71	Quartz.
·72	Marble.
·73	Granite.
·74	Slate.
·75	Lava.
·76	Asbestos.
·77	Sulphur.
·78	Amber.
·79	Celluloid.
·8	Other cellulose esters (viscose, etc.).
·81	Oxide coatings on metals.
·82	Stoneware, vitrified clay products, etc.
·83	Casein products.
·9	Miscellaneous.
R282	Electrolytes.
*R282·1	Water.
* ·2	Sulphuric acid solutions.
R283	Magnetic materials.
*R283·1	Ordinary iron and steels.
* ·2	Special electrical steels.
* ·5	Non-ferrous magnetic materials.
R284	Simple Conductors (*i.e.*, "conductors of the first class").
R284·1	Pure metals.
·11	Copper.
·13	Tungsten.
* ·2	Alloys.
*R285	Gaseous conductors.

This is reserved for general considerations. Applications such as the valve, the arc, and the spark, are dealt with elsewhere.

R290 Other measurements.

*** These subdivisions are proposed by us as a tentative further extension.**

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The Numans Oscillator.

By K. C. van Ryn. **[R344**

This circuit—a new one from Holland—may be used with either single or double grid valves, and makes an effective wave-meter.

IN valve-oscillator circuits, up to now, it has been the practice to use two coupled coils (Tickler coil), one with a centre tap (Hartley), or a single coil with a "tapped" condenser (Colpitts). For use as a heterodyne wave-meter all these circuits have the drawback of the necessary use of two coupled coils or two separate condensers, which make them difficult to handle and unsuitable for measuring purposes.

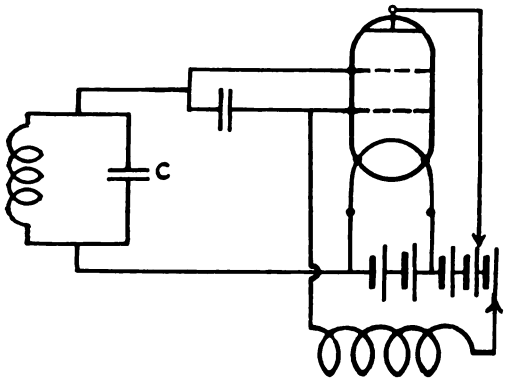

Fig. 1.

This article describes a valve circuit that sets up oscillations in *any closed circuit* containing inductance, capacity and resistance, such as an ordinary condenser and coil (wave-meter), a telephone winding, a transformer winding or an aerial circuit.

As in all usual valve-oscillator circuits we have different ways of feeding the valve. In Fig. 1 the valve is fed in shunt. Fig. 2 shows the same circuit but with series feed.

In Figs. 1 and 2 a double-grid valve is shown, but an ordinary one will do for this purpose. *The principle does not depend on any particular dimensions or on the use of a double-grid valve.*

The New System.

To explain the system we will consider first the characteristic curve of a double-grid valve, Fig. 3. In this type of valve the auxiliary grid (the one next to the filament) is kept at a positive potential, just like the anode. Auxiliary grid and anode will then each take a part of the total electron stream from the filament. Generally the auxiliary grid current and the anode current will not have the same value.

Assume that the control or outer grid is now brought to a negative potential: the electrons, which on their way from the filament to the anode have passed the auxiliary grid, will be pushed back and *partly* reach the auxiliary grid, instead of the anode.

A *negative* charge on the control grid thus causes an *increase* in auxiliary grid current. This happens in the part *bc* of the curve.

If we go on increasing the negative potential of the control grid, its field, which reaches through the meshes of the auxiliary grid, will at last become so strong that the electrons will be pushed back before having actually reached the auxiliary grid. When this occurs we observe a *decrease* of the auxiliary grid current, when *increasing* the *negative* control grid potential. We then

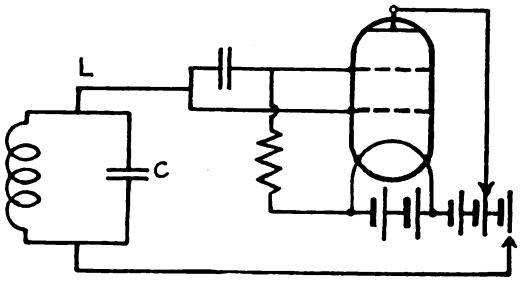

Fig. 2.

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come to the part *cd* of the curve where the fluctuations of the control grid voltage are in phase with the auxiliary grid current fluctuations. We mention this phenomenon in order to explain later on some deviations that may occur.

The same phenomena take place in a single grid valve, when using the anode as a "control grid" and the grid as an "auxiliary grid." However, with ordinary makes of single grid valves, the first part of the curve is very small and therefore unsuitable for our purpose. Ordinary makes of double grid valves are better, because in this case the field of the anode can assist the auxiliary grid field to pull the electrons through the meshes of the auxiliary grid.

In the case of this oscillator circuit we want the valve to work in the first part of the curve (*bc*), where the control grid voltage fluctuations are 180° out of phase with the auxiliary grid current fluctuations. Looking at the *combination* of the two grids, we find that this forms, *as regards the closed circuit*, a negative resistance device, *i.e.*, a negative potential on the control grid, induced by the closed circuit, gives rise to an increase of the auxiliary grid current, flowing through the same closed circuit.

It will therefore be clear that any circuit containing inductance, capacity and resistance, connected between the filament and the combination of the two grids, will start to oscillate at very nearly its own frequency.

Perhaps a more simple explanation of the operation of this oscillator circuit is the following :—

The closed circuit LC forms part of the control grid circuit (acting as an input circuit) as well as of the auxiliary grid circuit (acting as an output circuit). Thus the auxiliary grid circuit feeds back to the control grid circuit by means of the common closed circuit. As a result of the phase difference of 180° between the fluctuations of control grid potential and auxiliary grid current, this feed-back is in the right direction, so that oscillations are produced. In this circuit the maximum possible coupling between input and output circuits is obtained (100 per cent.).

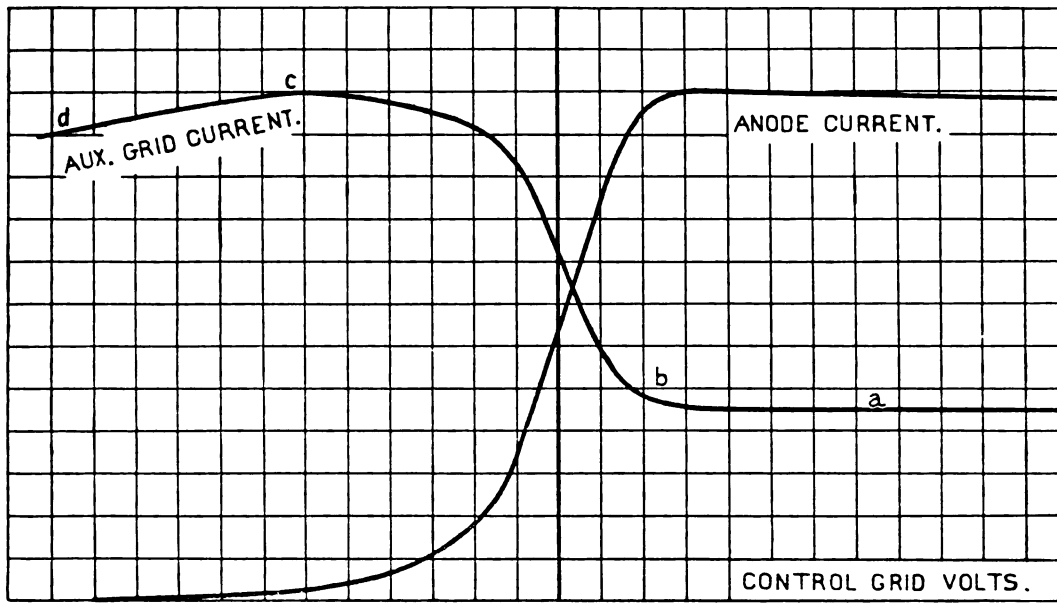

Fig. 3.

This is the principle of a new apparatus which opens a large field of extremely useful applications, not only for communication purposes, but also for accurate measurements.

A Handy Heterodyne Wave-Meter.

We will here describe a wave-meter for very short as well as for very long waves (up to a frequency of 20 per sec.), built on this principle. The circuit of Fig. 2 is particularly suitable for this purpose, as it

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contains a grid condenser and leak, which enables it to be used as a receiving wave-meter also. A photograph of the instrument is shown in Fig. 4, and the practical circuit will be found in Fig. 5.

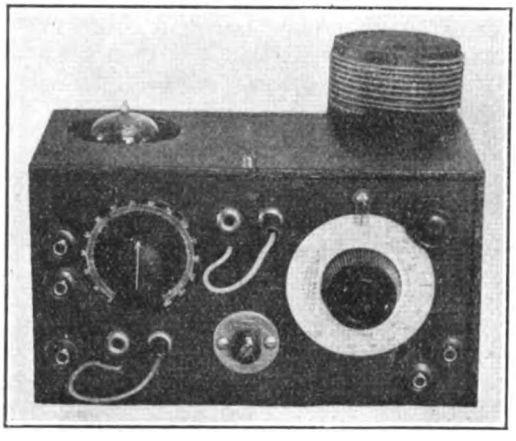

Fig. 4.

A General Radio condenser of ·000 27μF is used, with vernier adjustment, and has proved very suitable, even for wave-lengths down to 10 metres. The batteries have been shunted by a condenser C_3 of ·002μF for eliminating hand-capacity effects. Condenser C_2 is the telephone by-pass condenser (·002μF), which can be short-circuited by a plug. C_1 is a stopping condenser which, in combination with the leak R, gives rectification in the grid circuit. The value is ·000 2μF. The grid leak is a Watmel (0·5—5 MO), but its value is not at all critical; it should not exceed about 1 MO.

We have used several makes of double-grid valves, such as: "Philips" (Dutch) with ordinary and dull-emitter filaments; "Heussen" (Dutch); "Telefunken" (German) type R.E. 26 and R.E. 25; "Siemens-Schottky (German); all giving equally good results.

The filament resistance is placed in the *positive* filament lead. Between filament resistance and terminal is interposed a flexible lead and plug as also across condenser C_2. The plugs are placed in such a way that, with the filament glowing, the anode can be plugged directly to the positive filament terminal. This done, the anode is always at filament potential (see later). The oscillator may be connected to the same batteries as the receiver.

Oscillation.

To find out if the wave-meter oscillates, plug telephones into the anode circuit (at C_2 in Fig. 5) and touch the grid side of the closed circuit with a wet finger.

When the filament burns too brightly, the set will howl or stop oscillating, especially when using too little high tension. On long waves the filament should not burn too brightly; with a bright-emitter filament, *red* suffices. On short wave-lengths, under 200 metres, the filament may burn at its normal temperature. The more high tension is used, the brighter the filament should be and the stronger will be the oscillations.

An explanation of this phenomenon might be the following: Oscillations will stop when the free negative charge on the control grid reaches such a value, that the valve works on a point past C in the curve of Fig. 3.

When observing the beat note with an oscillating receiver on waves longer than 500 metres, a very small change will be observed on changing the filament or high tension voltages, just as with every other heterodyne wave-meter. On the other hand absolute constancy can be obtained by connecting the anode to the filament positive. The plug system illustrated makes this possible.

This heterodyne wave-meter can be calibrated easily, using harmonics (this with full

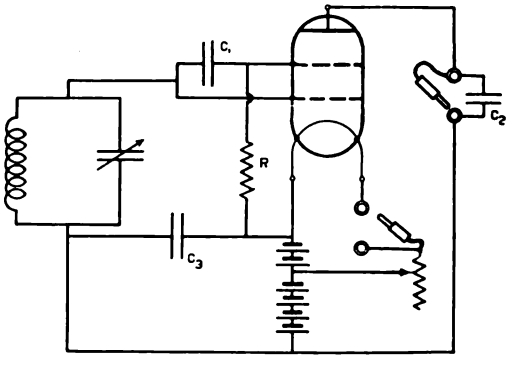

Fig. 5.

anode voltage). The "click-method" is found very handy.

In addition, this apparatus permits of making accurate measurements of capacity, self-capacity of coils, inductance and aerial constants. Low-frequency transformers can also be tested.

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Short-circuited Turns as an Aid to Reception on Short Waves.

By W. E. Benham. [R382

In this article the author shows how, by short-circuiting one or more turns of the reaction coil, oscillation on short waves is made easier. Further to the author's explanation of this we give an alternative one in an Appendix.

Introductory.

SHORT waves have been found efficient by amateurs. Shorter waves have been and are being found more efficient still. Last year it was 100 metres, this year it is 50 and even less. No sooner do we find KDKA on 66 metres than we learn that WGY has contented itself with 15·8; and in this headlong rush down the wave-length scale, many are left behind.

In low-wave reception everything (except mechanical essentials) must be sacrificed to efficiency. Special attention must be paid to all wires carrying high frequency currents, and thick wire should therefore be used, not only in the aerial and grid circuits, but also in the plate circuit. The phones, high tension and even accumulator should be shunted by condensers.

Spacing of wire on the aerial coil is very necessary, and a low capacity valve should be used; a soft Dutch valve however seems to answer the purpose very well. The grid-condenser should preferably be of air dielectric: in fact as little dielectric as is compatible with mechanical considerations should be used in the construction of the receiver.

Damping.

Why all the above cautions? The one word "Damping" provides the answer. On long waves the damping reduces mainly to the high frequency resistance of conductors in the receiver, in particular the aerial coil. On short waves losses due to dielectric absorption, eddy currents on neighbouring objects and capacity losses in one form or another become serious. These losses can be reduced, but not eliminated. They have to be compensated for by transfer of energy from the plate to the grid circuit of the valve. When the energy so transferred is equal to or greater than the energy lost by damping, oscillation occurs.

Conditions for Regeneration.

In order that the energy fed back into the grid circuit may be sufficient to overcome damping, there must be a sufficient field: in the case of the reaction coil this means sufficient "ampère turns." Now the "ampère turns" of a reaction coil reach a maximum when the coil is tuned to the same wave-length as the aerial circuit; but simplicity in tuning being highly desirable in short-wave work, it is unwise to tune the reaction coil as well as the aerial circuit, especially as this produces in the set a very unstable condition of oscillation. It is found that tuning is easiest when the reaction coil is tuned to a wave-length just below that being received. The field in the reaction coil is then somewhere near the maximum value.

The number of turns is very critical on short waves, and it is advisable to have tappings every two turns on a coil 3 in. in diameter. It is hardly necessary to point out that the use of tappings, being a rough method of tuning, is not nearly so laborious as tuning the coil exactly for any wave-length. One tapping will serve for quite a large range of tuning, and once this range has been found by trial for each tapping, the right tapping for use with any wave-length is known.

Now on shorter waves the field in the reaction coil tends to become less, while there is more damping to be overcome and to make matters worse there are fewer turns in the grid circuit available for coupling. Hence the main difficulty in getting the receiver to oscillate on short waves.

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The Grid Coil.

A device for increasing the grid turns available for coupling is due to Hartley, who included a number of turns in the grid circuit whose function is to increase the mutual inductance between plate and grid circuits, and so collect more energy. As these grid turns are to be aperiodic however, they cannot be increased indefinitely. The arrangement is shown in Fig. 1. This circuit oscillates nearly as easily as a loose-coupled circuit, and is simpler to operate. The lower wave-length limit of either circuit is reached when the turns in grid and plate circuits are too few to provide the necessary coupling.

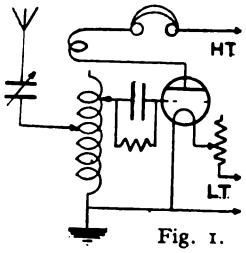

Fig. 1.

Decreasing Wave-length.

If the turns in the reaction coil could be increased without altering the natural wave-length, oscillation would be easier. This can be done by short-circuiting one or more turns of the reaction coil. When any current flows in the coil, the short-circuited turn acts like the secondary of a transformer, and a large induced current is set up in it. This current in turn sets up a magnetic field which is always opposed to that set up by the coil itself. Since the inductance of a coil is measured by the magnetic field to which it gives rise, the apparent inductance is decreased.

It will at once be asked: "What is the gain in field strength if the field due to a given inductance (apparent or otherwise) is always the same?" In other words, we may obtain the same inductance by doubling the turns and short-circuiting the end one, but the field produced is no greater, hence no more energy is handed back to the grid circuit.

The explanation of this lies in the fact that the induced and inducing currents are out of phase. For large frequencies they are very nearly 90 degrees out of phase. The result is that *at a given instant* the induced and inducing currents are going in opposite directions, and the fields set up will actually assist one another. At a given instant the induced current has not been caused by the simultaneous main current, but is due to that current an instant before. So that it is still true to say that the fields due to inducing and corresponding induced currents oppose one another, while the fields to the synchronous inducing and induced currents assist one another.* Since the short-circuited turn acts like a separate circuit, we may regard it as such for purposes of examination. If L_1 be the actual inductance of the main coil, L_2 that of the single turn, M the coefficient of mutual inductance between the two, R_2 the resistance of the single turn, and $\omega=2\pi n$, where n is the frequency, then the apparent inductance of the main coil is

$$L_1-\omega^2M^2L_2/(R_2^2+\omega^2L_2^2).$$

Since ω is very large and R_2 is small, we may neglect R_2^2 in comparison with $\omega^2L_2^2$. The apparent inductance is then

$$L_2-\frac{M^2}{L_2}$$

While the apparent inductance is diminished, the apparent resistance is increased. R_1 being the actual resistance, the apparent resistance is

$$R_1+\frac{\omega^2M^2R_2}{R_2^2+\omega^2L_2^2}=R_1+\frac{M^2R_2}{L_2^2}$$

(neglecting R_2^2).

The above formulæ assume that capacity is negligible. This is justified, as the capacity across the reaction coil is very small. Since we are not tuning the reaction coil exactly, but only roughly by tappings, the increase of apparent resistance will be masked by the presence of apparent reactance, so that very little extra damping will arise from increase of apparent resistance.

Results Obtained.

The writer was using a Hartley circuit, the only addition being an extra clip attached to the tapping-lead of the reaction coil, enabling one or more turns to be short-circuited. The writer always uses a counterpoise instead of an earth with this circuit, in order to reduce the damping of the aerial circuit. This is not necessary if a loose-coupled receiver is used. (See Fig. 2.)

It was found that the lower limit of wave-length was reduced to nearly half by simply short-circuiting turns in the reaction coil. The particular reaction coil used was 6 in.

* An alternative explanation is given in the Appendix.

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in diameter, with tappings every turn up to the fifteenth, and every two or three turns up to the sixtieth, there being 60 turns in all. It was also found that regeneration was further increased by short-circuiting several turns at once; but there is one caution which must be emphasised here. If too many turns are short-circuited they may act as a wave trap if they are anywhere near resonance with the grid circuit.

There are several combinations which work about equally well on a given wave-length. Thus it is immaterial whether the thirtieth and fortieth turns are short-circuited, or the thirty-second and forty-fifth, to take an example. Hence no difficulty should be found in choosing the right turns to short circuit.

The lowest wave-length without short-circuiting turns on which the set would oscillate, using outdoor aerial and counterpoise, was about 60 metres at the time of experiment. With the turns short-circuited, wave-lengths as low as 35 metres were received, 2LO's harmonics being the standard on which this estimation was gauged. Thus no fewer than 10 harmonics were heard below the fundamental (365 metres), so that assuming none were missed, which is probable, the wave of the lowest was 36·5. If any were missed, it must have been lower still.

The arrangement can be used with advantage on all waves below 200 metres because then the reaction coil need not be coupled nearly so tightly, and any variation in coupling will only produce a slight change in wave-length, so that tuning is much easier.

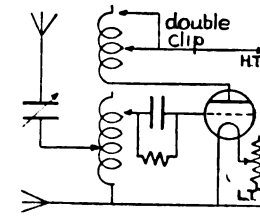

Fig. 2.

The increased oscillation is no sign of instability: on the contrary it is probable that there is a stabilising effect. Also one set of tappings covers a much wider range of wave-lengths than a single tapping on an ordinary coil.

APPENDIX.

This is a curious point: that by increasing the turns and then shorting some of them, the inductance of the coil can remain as before, but that stronger coupling can be obtained. Personally, we believe that the effect is due to the fact that the coils used in wireless are not entirely concentrated; *i.e.*, the coupling between the turns at one end and those at the other is quite small. In consequence the increase of turns gives a greater *mutual* inductance, because there are more turns coupled to the grid-coil. The reverse field set up by the shorted turns, on the other hand, affects most strongly the turns at the far end of the coil and not those nearest the grid-coil. This exposition is a very condensed one, we fear.—ED. E.W. & W.E.

ERRATA.

One or two errors crept into articles in our November issue, and we beg our readers to make the necessary corrections, which are as follows:—

"An Easy Way to Calculate Circuits."

P. 72, col. 2.

$$L = \frac{167}{\omega} = 88\mu H.$$

The result here should be $84\mu H$, and the same change should be made two lines down.

Same page and column.

The last two equations, which read

$$\frac{1}{Z} = \frac{833j - 20 - 1\,000j}{833j\,(20 + 1\,000)}$$

$$= \frac{-20 - 167j}{833\,000 + 16\,700j}$$

are incorrect owing to a printer's error, and should be:—

$$\frac{1}{Z} = \frac{833j - 20 - 1\,000j}{833j\,(20 + 1\,000j)} = \frac{-20 - 167j}{-833\,000 + 16\,700j}$$

"Intervalve Transformers."

P. 75, equation (35).

The first part of the denominator is given as

$$[1 - L_2C_2\omega^2(1 - k_2)^2]$$

it should actually be

$$[1 - L_2C_2\omega^2(1 - k^2)]^2.$$

P. 79, Table II., last column, ninth line, 4·86 should be — 4·86.

"Notes on Power Transformer Design."

P. 105, col. 1, six lines from bottom,

$$E.M.F. = 4{\cdot}44\,f\,A\,B\,10^8 \text{ volts}$$

This should be

$$E\,M\,F = 4{\cdot}44\,f\,A\,B\,10^{-8} \text{ volts}$$

and the same applies to line 7, column 2.

We are asked by Messrs. Beard & Fitch to state that the price of their "Success" transformer is 21s. and not 10s. as appeared in the advertisement on page iv of the cover.

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The Graphical Analysis of Composite Impedances. [R140

By F. M. Colebrook.

In this paper the author considers some of the important arrangements of impedances met with in practical wireless telephony and telegraphy, and shows their characteristics graphically.

THE graphical representation of the solution of any problem involving quantitative relationships has the important practical advantage, due to its direct appeal to the sense of sight, of being very readily understood.

The object of the present paper is to consider some of the most important arrangements of impedances met with in practical wireless telegraphy and telephony and to show their behaviour in pictorial form. It is hoped that in this way even those whose mathematical equipment is insufficient to enable them to follow all the reasoning involved will, nevertheless, be able to obtain a complete grasp of the most significant features of the results.

The sign and direction conventions on which the diagrams are based are virtually those implied in the so-called "symbolic" method of analysis of alternating current

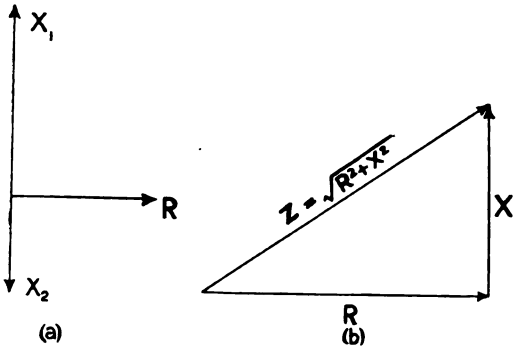

Fig. 1.

problems. Thus, a line in the direction of the bottom edge of the paper from left to right will be used to represent a pure resistance. The scale is, of course, immaterial, provided one scale is adhered to in any one diagram. Taking the scale to be one unit of length for one ohm, then a line R units long will represent a resistance of R ohms. In a similar manner a positive reactance, *i.e.*, the reactance associated with a pure inductance, will be represented by a line

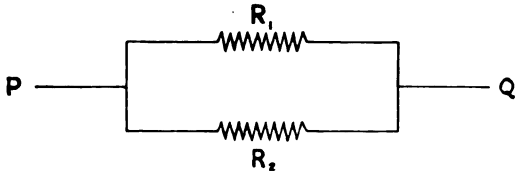

Fig. 2.

of appropriate length drawn upwards and parallel to the edge of the paper, and conversely, a negative reactance, *i.e.*, the reactance associated with a pure capacitance, will be represented by a line of appropriate length drawn downwards in a direction parallel to the edge of the paper.

This system of representation is illustrated in Fig. 1*a*, which shows a pure resistance of R ohms, a pure positive reactance of X_1 ohms, and a pure negative reactance of X_2 ohms. In addition, Fig. 1*b* shows in the same way the line representing an impedance consisting of a positive reactance X in series with (*i.e.*, added to) a pure resistance R. The magnitude of this impedance is clearly given by

$$Z=\sqrt{R^2+X^2}.$$

In symbolic notation the same impedance is represented by

$$Z=R+jX \quad .. \quad .. \quad (1)$$

the symbol j indicating that in the graphical representation of Z the line representing X must be drawn in a direction making $+90°$ with that representing R.

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The rather elementary nature of this introduction must be excused on the ground that sign and direction conventions play a very important part in all that follows.

2.—Two Pure Resistances in Parallel.

This case, illustrated in Fig. 2, may seem too simple to need any pictorial aid for its comprehension. It is included, however,

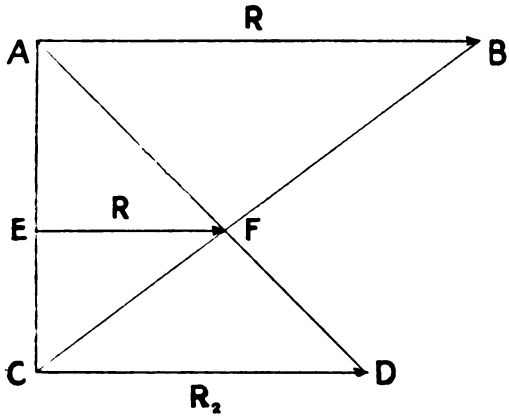

Fig. 3.

because the diagram introduced in this connection will be found to have other and more important practical applications.

It is well known that the impedance between the points P and Q is a pure resistance R given by

$$\frac{1}{R}=\frac{1}{R_1}+\frac{1}{R_2} \quad .. \quad .. \quad (2)$$

The corresponding diagram is probably less well known. Let AB and CD in Fig. 3 represent R_1 and R_2 respectively, the distance AC being any convenient length. From the elementary properties of similar triangles we have

$$\frac{EF}{CD}=\frac{AE}{AC} \text{ and } \frac{EF}{AB}=\frac{EC}{AC} \quad .. \quad (3)$$

By the addition of these two equations

$$EF\left(\frac{1}{CD}+\frac{1}{AB}\right)=\frac{AE+EC}{AC}=\frac{AC}{AC}=1 \quad (4)$$

Therefore

$$\frac{1}{CD}+\frac{1}{AB}=\frac{1}{EF} \quad .. \quad .. \quad (5)$$

i.e.,

$$\frac{1}{R_1}+\frac{1}{R_2}=\frac{1}{EF} \quad .. \quad .. \quad (6)$$

By comparing equation (6) with equation (2), we see that

$$EF=R$$

The diagram makes very clear the fact that, whatever the magnitudes of R_1 and R_2, R will always be less than either of them. The graphical representation of this case

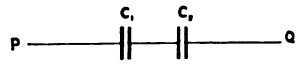

Fig. 4.

may appear to be of theoretical rather than of practical interest. Actually, however, the writer found the diagram very convenient for use in connection with the design of a multi-range stud rheostat for the filament control of different types of valves or of various numbers of valves of the same type, the variation of range being effected by means of shunt resistances connected across one end of the main resistance and the switch arm.

3.—Condensers in Series.

For the case illustrated in Fig. 4 the effective capacity between the points P and Q is given by C where

$$\frac{1}{C_1}+\frac{1}{C_2}=\frac{1}{C}$$

The summation of capacities in series can therefore be represented by a diagram exactly similar to that described above, two vertical lines being drawn to represent the capacities C_1 and C_2. This is illustrated in Fig. 5. It is not really a reactance diagram in the sense suggested in the introduction, but it is nevertheless a very convenient way of representing the behaviour of two condensers in series. As an example of its practical application we may take the case in which a variable condenser of ·001 μF maximum value is converted into a variable condenser of, say, ·000 3 μF maximum value by putting a small fixed condenser in series with it. This is illustrated in Fig. 6. Draw AB_{10} to represent ·001 μF.

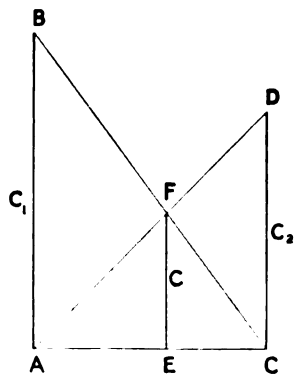

Fig. 5.

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to a given scale, and AC, of any convenient length, perpendicular to AB_{10}. Join C to B_{10}. Let F_{10} be the point on CB whose ordinate is ·0003. Then, if AF_{10} cuts the line perpendicular to AC at D, CD is the magnitude of the fixed capacity required. Further, if AB_1, AB_2, AB_3, etc., represent the variable condenser scale readings for ·0001, ·0002, ·0003, etc., μF, then the ordinates of the points F_1, F_2, F_3, etc., will give the total capacity of the series combination. The calibration of the variable condenser being known, the calibration of the combination can be read off directly from such a diagram.

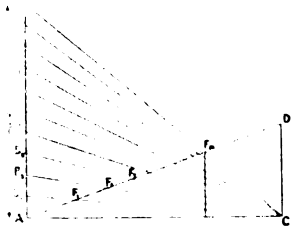

Fig. 6.

4.—The General Case of Impedances in Parallel.

If a number of impedances Z_1, Z_2, Z_3, etc., representing respectively, R_1+jX_1, R_2+jX_2, R_3+jX_3, etc., be connected in parallel, then it can be shown that the resultant impedance is given by Z where

$$\frac{1}{Z}=\frac{1}{Z_1}+\frac{1}{Z_2}+\frac{1}{Z_3} \text{ etc., etc. } (7)$$

In fact, impedances in parallel combine according to the same law as resistances in parallel, but it must be remembered that

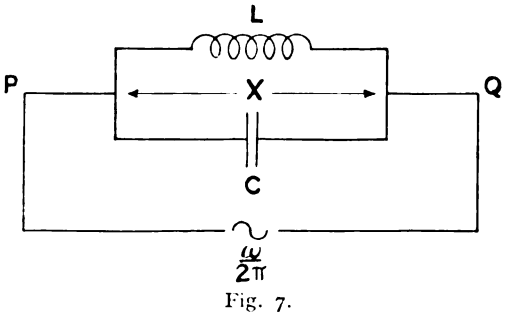

Fig. 7.

in the further development of equation (7) the quantities Z_1, Z_2, Z_3, etc., are similar to and obey the same laws as complex numbers of the type $a+b\sqrt{-1}$. The object of the present paper is, however, to eliminate mathematics as far as possible, or rather to simplify it by means of graphical representation. At present the writer has not found any really simple and convenient graphical representation for the general case. Fortunately, however, the particular cases of the above which are of most importance from the point of view of practical wireless telegraphy and telephony are fairly simple in type, and lend themselves readily to graphical treatment with very useful results.

5.—A Pure Inductance and a Pure Capacity in Parallel.

This important case is illustrated in Fig. 7. At a frequency $\omega/2\pi$ the reactance of the inductance will be $j\omega L$, *i.e.*, it will be represented by a line of length ωL measured upwards in a direction parallel to that of the edge of the paper. Similarly the reactance of the capacity at the same frequency is $-j/\omega C$, *i.e.*, it will be represented by a line of length $1/\omega C$ measured in the opposite direction to that representing the reactance of the inductance. The two lines are represented by AB and CD respectively in Fig. 8. If Z be the impedance of the two in parallel between the points P and Q we have, as indicated in equation (7),

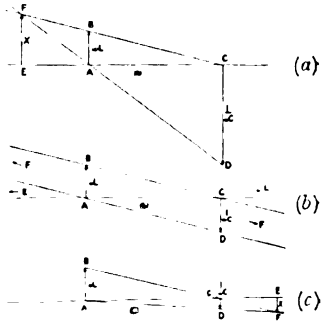

Fig. 8.

$$\frac{1}{Z}=\frac{1}{j\omega L}+\frac{1}{-j/\omega C} \quad .. \quad (8)$$

$$=\frac{1}{j}\left(\frac{1}{\omega L}-\frac{1}{1/\omega C}\right) \quad .. \quad (9)$$

Now complete the diagram of Fig. 8 in exactly the same way as in the case of the resistances in parallel, or the condensers in series, *i.e.*, join AD and BC, and from F, the point of intersection of these two lines, draw EF perpendicular to AD. Then exactly as in the previous cases, it can easily be shown that EF represents the reactance of the two branches in parallel.

The sign and magnitude of this reactance in terms of the relative magnitudes of the component reactances is very easily deduced from the diagram. For the larger values of $1/\omega C-\omega L$, EF will be as shown in Fig. 8*a*, and the combination behaves like a pure inductance of magnitude greater than that

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of L. As $1/\omega C$ decreases, this being effected by increasing either C or the frequency, the magnitude of EF increases steadily until $1/\omega C = \omega L$, when, as shown in Fig. 8*b*, EF becomes infinite and indeterminate in sign. As $1/\omega C$ decreases still further till it is less than ωL, then, as shown in Fig. 8*c*, EF becomes negative, *i.e.*, the combination behaves like a pure capacity of magnitude smaller than C. It should be noted that so long as both L and C are respectively a pure inductance and a pure capacity, containing no resistance terms, then the reactance of the two in parallel, even when it becomes infinite, will be a pure reactance and will contain no energy-consuming term. These conditions cannot, however, be realised in practice. It is impossible completely to eliminate resistance either from L or C, particularly at radio frequencies, and the resistance terms, though small,

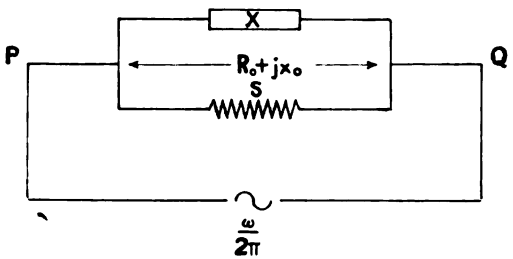

Fig. 9.

will profoundly modify the above behaviour. The diagram is nevertheless of considerable value as illustrating the general behaviour of the two in parallel, and, in conjunction with the more complete diagram which will now be considered, one which take the resistance terms into account, it gives a very complete idea of what happens when an inductance is tuned to a given frequency by means of a parallel variable condenser.

6.—The General Case of a Pure Resistance in Parallel with a Pure Reactance.

The circuit to be considered is illustrated in Fig. 9. If

$$Z = R_0 + jX_0$$

be the symbolical expression for the impedance between the points P and Q, then, as indicated in equation (7) :—

$$\frac{1}{Z} = \frac{1}{R_0 + jX_0} = \frac{1}{S} + \frac{1}{jX} = \frac{1}{S} - \frac{j}{X} \qquad (10)$$

Now consider the diagram of Fig. 10, in which OA=X in magnitude and is drawn up or down according to the sign of X, OB=S, and OD is drawn perpendicular to AB, CD being perpendicular to OB.

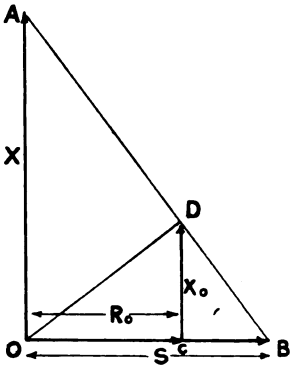

Fig. 10.

From the geometry of similar figures it follows that

$$OC = R_0$$
$$CD = X_0$$

Given, therefore, a known pure reactance X shunted by a known pure resistance S, we have here a very simple diagram for determining in one operation both the effective reactance and the effective resistance of the two in parallel. Further, the line OD clearly represents the effective impedance of the combination. The application of the diagram is not confined to this, however, for, as will now be demonstrated, it not only gives the quantitative solution for any given values of X and S, but will also delineate the result of varying either or both of these factors.

Let us consider first the effect of keeping S constant and varying X between the limits minus and plus infinity, either by varying the inductance and capacitance components or, keeping these constant, by varying the frequency. Wherever the point A may go on the line OA, over the whole of its range from an infinite distance below, to an infinite distance above OB, the angle ODB remains a right angle by construction. The locus of D is therefore a circle on OB as diameter. This is shown in Fig. 11. This interesting result can be expressed in words in the following way: If a pure resistance of magnitude S is shunted by a pure reactance whose magnitude is varied from minus infinity to plus infinity,

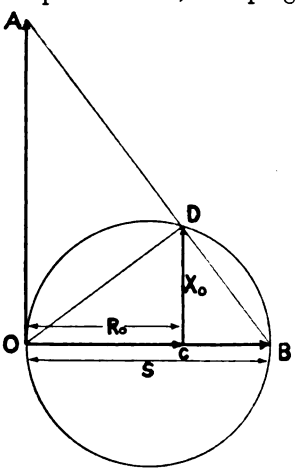

Fig. 11.

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then the line representing the impedance of the two in parallel is such that, one end being fixed, the other moves round a circle of diameter equal to the magnitude of S.

Before discussing this result in greater detail we will consider the result of the alternative type of variation, that in which X is kept constant and S is varied from 0 to plus infinity. (It should be noted that S is considered to be always positive. This means that the rather special case of so-called negative resistance is, for the present, excluded from the discussion.) In terms of the diagram of Fig. 10, we have the condition that OA is constant and that OB may have any magnitude from 0 to plus infinity. It is clear that, whatever the position of B in the line of its travel, ODA remains a right angle. The locus of D is therefore a semi-circle on OA as diameter, by construction. The complete diagram, representing the result of the variation of either factor from the initial value X or S, the other factor remaining constant, is therefore as shown in Fig. 12. This last result can be stated in words in the following manner:—

If a pure reactance of magnitude X is shunted by a pure resistance whose magnitude is varied from zero to plus infinity, then the line representing the impedance of the combination is such that, one end being fixed, the other moves round a semicircle of diameter equal to the magnitude of X.

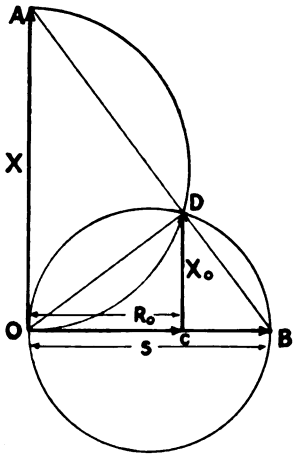

Fig. 12.

The result of simultaneous variations of X and S could, of course, be illustrated on a universal diagram covering all possible values of X and S, this diagram consisting of family of circles of constant S intersecting a double family of semicircles of constant X, one set corresponding to negative and the other to positive values of X. Such a diagram would undoubtedly have useful practical applications.

Before considering the relation of the above circle diagrams to practical problems encountered in wireless telegraphy and telephony, one important characteristic of the constant shunt resistance case should be noted. It is clear that, in general, the

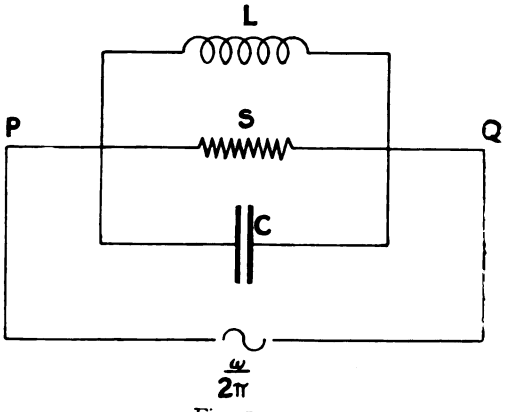

Fig. 13.

effect of the shunt resistance is to make the effective reactance X_0 smaller, in some cases very much smaller, than the true reactance X. Moreover, while there are no limits to the possible values of X, there are very definite limits to the value of X_0, the positive limit being $+S/2$ and the negative limit being $-S/2$. Again, the effective impedance has a definite maximum value S, corresponding to the values $\pm\infty$ for X, the impedance under these conditions being wholly resistive.

7.—Inductance, Capacity, and Resistance in Parallel.

A combination of the results of paragraphs 5 and 6 gives a very simple graphical analysis for the case, frequently encountered in practice, illustrated in the diagram of Fig. 13. The diagram is drawn for a typical case in Fig. 14, and needs no further description in view of what has gone before.

8.—The Effect of the Distributed Resistance of an Inductance.

At a frequency $\omega/2\pi$ the impedance of a coil of inductance L and resistance R is given by

$$Z = R + j\omega L \quad .. \quad .. \quad (11)$$

By a simple transformation we have

$$\frac{1}{Z} = \frac{R - j\omega L}{R^2 + \omega^2 L^2} \quad .. \quad (12)$$

$$= \frac{1}{R + \omega^2 L^2/R} + \frac{1}{\omega j(L + R^2/\omega^2 L)} \quad .. \quad (13)$$

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The impedance of the coil can therefore be represented as that due to an inductance $L+R^2/\omega^2L$ shunted by a pure resistance $R+\omega^2L^2/R$. For relatively low resistance

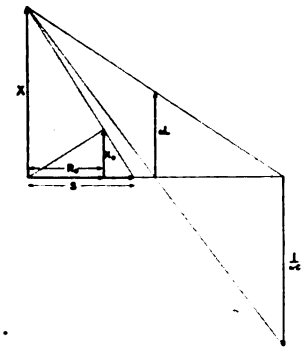

Fig. 14.

coils at radio frequencies R will be negligible compared with ω^2L^2/R, and L will be large compared with R^2/ω^2L. If this coil is used with a parallel tuning condenser we have the closely approximate equivalence represented in the diagram of Fig. 15. For a given value of L and a constant frequency the shunt resistance ω^2L^2/R is a constant. The case is therefore that considered in paragraph 6, *i.e.*, a pure variable reactance shunted by a constant resistance. Referring to the appropriate circle diagram (Fig. 11), it will be seen that the maximum impedance obtainable by the tuning of the coil is the magnitude of the shunt resistance ω^2L^2/R. The effect of the distributed resistance is thus seen to be that, instead of being able to tune the coil to an infinite wholly reactive impedance, it can only be tuned to a finite wholly resistive impedance.

This distinction has considerable practical importance in the case where the coil is being used in the anode circuit of a valve in a tuned anode circuit amplifier. The practical requirement then is that the impedance shall have as high a value as possible, at least 100 000 ohms. Suppose now that we have the numerical values: L, 100 microhenries; ω, 5×10^6 (corresponding approximately to the frequency of the transmission form 2LO); R, 10 ohms. (It must be remembered that the resistance is that corresponding to the high frequency at which the coil is being used. This will in general be very much greater than the D.C. resistance of the coil.) The maximum impedance obtainable by tuning this coil is seen to be $25\times10^{12}\times100^2\times10^{-12}/10$, *i.e.*, 25 000 ohms. Such a coil would clearly be very inefficient in a tuned anode circuit. If some fixed minimum value for the impedance be taken as the standard to be attained, say, 150 000 ohms, then there is clearly a definite upper limit which R must not exceed for any given value of L. This is illustrated in the table below for a frequency corresponding to $\omega=5\times10^6$.

L in microhenries.	Tuning capacity in $\mu\mu$F.	Upper limit for R.
100	403	1·7
200	202	6·7
300	134	15
400	101	27
500	81	42
1 000	40	167

It is clear that, in general, the conditions will be most easily fulfilled by making L as large as is practicable, the upper limit in this direction being the self-capacity of the coil.

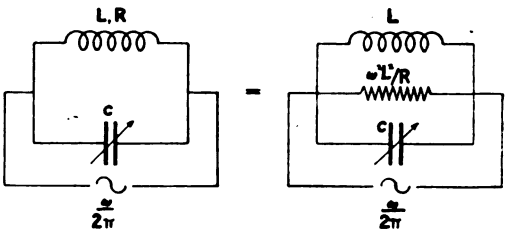

Fig. 15.

The above analysis shows how essential it is that coils for use at high frequencies should be constructed in a way which minimises both the self-capacity and the high frequency resistance. The ideal type is probably a single layer solenoid or helix wound with low resistance wire, preferably stranded, the turns being well spaced (at least two diameters of the wire apart) the mounting being some form of frame (of insulating material) which minimises the proximity of the wire to any solid dielectric. Such coils cannot, of course, be made very compactly, but in this matter compactness is incompatible with high efficiency.

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Effective Resistance.

By Marcus G. Scroggie, B.Sc. **[R143**

In this article the author deals with sources of loss, which can often be considered as if produced by a resistance. It may be explained that he abbreviates "Effective Resistance" and "Ohmic Resistance" to E.R. and O.R. respectively.

MANY of the present-day radio experimenters are those who previously worked with ordinary "battery" or "mains" electricity, and were swept into wireless work before they had become acquainted with its rather formidable theory. To them it is often rather puzzling to find the term "resistance," which in their previous work had such a definitely simple meaning, used in a variety of ways totally different to that familiar in Ohm's Law. As "effective resistance" is of such importance, and such a useful idea when understood, a few notes on the matter may not be amiss.

As an example of the confusion which may arise through lack of a clear understanding of what resistance may mean, the case of the condenser is given. Everybody who knows anything about electricity from the D.C. standpoint, knows that a condenser should have a resistance (ohmic) of hundreds of megohms; that is to say, if a steady E.M.F. is applied to it, and the minute current leaking through it measured by an ultra-sensitive galvanometer, the ratio of the two should be of the order of 10^8 or more. On the other hand, books and papers which give what is intended to be a simple explanation of the behaviour of a condenser in an A.C. circuit frequently say that the current passing through a condenser depends upon the alternating voltage, and what may be termed the "resistance" of the condenser, which depends upon the frequency. This is misleading in two respects, and whilst by avoiding the use of the proper word, reactance, it may seem to make the matter clearer to begin with, it only makes it more difficult for the reader when he pursues the subject further. To begin with, the current does not flow *through* the condenser at all, but flows *in and out*, just as air can flow in and out of a rubber balloon when the pressure at the entrance is varied, though no air flows *through* it. If this is realised, the "D.C. man" will have no difficulty in reconciling the current, perhaps quite large, with the almost infinite resistance of the condenser. Secondly, the use of the word resistance instead of reactance is a pure inaccuracy, and the most elementary principles of A.C. can never be grasped so long as it is retained. The only thing reactance has in common with resistance is its unit of measurement, the ohm. The fact that the word reactance is often used when reaction is meant only increases the confusion.

Accordingly, we will rule out this spurious meaning of resistance. But there is yet another, and correct, use of the word in connection with a condenser, which may be distinguished by calling it effective or equivalent resistance as distinct from ohmic. This should always be low in a condenser, and may be a small fraction of an ohm, hence it introduces an entirely new concept of resistance, for, as mentioned before, the ohmic resistance is, or should be, very high indeed. The effective resistance of a condenser is that value of ohmic resistance which, when connected (usually in series, if in parallel it is stated so) with a *perfect capacity* (no leakage or other losses) of the same value, would give rise to the same number of watts loss with a given E.M.F. and frequency. To be strictly accurate, it must be mentioned that a pure sine wave of E.M.F. is assumed. The same definition will hold for an inductance, or any circuit, such as an aerial, a loose-coupled receiving inductance, etc. The whole problem centres around the fact that in real life the three "constants" of circuits—resistance, inductance, and capacity—can never be obtained alone; *e.g.*, every coil besides inductance

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also possesses resistance and capacity, and this discrepancy between the real and the ideal is more marked the higher the frequency. It is quite possible for a coil of wire to act electrically as a condenser, the inductive effect being of less magnitude. Now, it is very difficult to make calculations such as are essential to radio design particularly if each of our components is a complicated mixture of these three "constants"; it is much simpler to sort them all out and substitute (on paper) a circuit in which the condensers are all capacity, the coils all inductance, and the resistances nothing but resistance. Then we can apply simple formulæ and know what we are doing.

It is when we come to sorting them out that we find it rather complicated, as there are so many variables. To take a simple case first: Suppose a condenser of capacity $0{\cdot}05\mu F$ connected up to 30 volts A.C. at 100 000 cycles (3000 metres wave-length). The reactance,

$$\frac{1}{2\pi fC} \text{ or } \frac{1}{\omega C}$$

as it is usually written, works out

$$\frac{1}{2\pi \times 10^5 \times 0{\cdot}05 \times 10^{-6}} = 32 \text{ ohms.}$$

Therefore the current flowing is $30/32 = 0{\cdot}94$ ampère. At least, that is what it should be if it were a perfect condenser. The current would lead the E.M.F. by 90°, there would be no component of current in phase with the E.M.F., and, consequently, no power supplied to the condenser. The losses would be nil. The vector diagram would be as in Fig. 1.

But condensers are subject to at least three sources of loss. There is the leakage through the medium between the plates, the loss in the resistance of the plates themselves, and the loss in the medium or dielectric due to "dielectric hysteresis." All these losses appear in the form of heat. Now, the amount of heat produced per second in a resistance is proportional to I^2R, this latter quantity is also numerically equal to the watts lost in the resistance, so clearly the E.R. of the condenser is equal to the watts lost in it divided by the current squared. The imperfect condenser behaves the same as a perfect condenser plus a perfect resistance (non-reactive) equal to the E.R. As power is being expended in the condenser, the current must be less than 90° out of phase with the E.M.F., and may be considered to be split up into two components, I_1 90° leading and I_2 exactly in phase (Fig. 2). I_2E is the power lost, so the

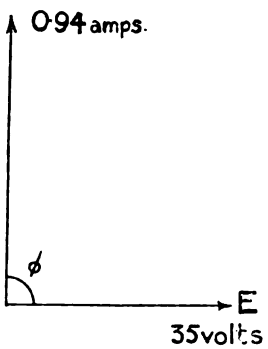

Fig. 1.

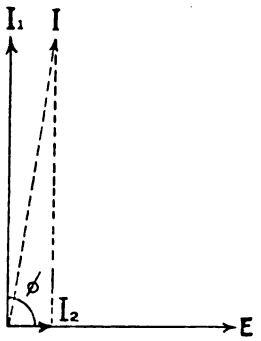

Fig. 2.

$$\text{E.R.} = \frac{I_2E}{I^2} = \frac{E \cos \phi}{I}.$$

Cos ϕ is what is called the "power factor" of the condenser, and should be very small. This indicates how the E.R. may be found by measurement: by applying an alternating E.M.F. and measuring the power with a wattmeter, and also the current. But in most cases the power is so very small, and a wattmeter so inaccurate with low power factors, that this method will not do, and the practical methods usually depend on substituting a standard condenser of negligible or known resistance. To show how leakage affects the E.R., suppose the insulation resistance of the $0{\cdot}05\mu F$ condenser previously considered is 50 megohms, so that leaving the other factors out of consideration the circuit is as in Fig. 3. The problem is to find what is the O.R. to be placed in series with the condenser to produce the same loss and phase angle as this leak. The current flowing *through* the condenser, *i.e.*, through the leak, is

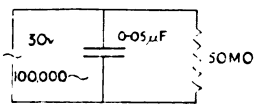

Fig. 3.

$$\frac{30}{50 \times 10^6} = 0{\cdot}6 \times 10^{-6} \text{ amp.}$$

The loss is therefore

$$(0{\cdot}6 \times 10^{-6})^2 \times 50 \times 10^6 = 18 \times 10^{-6} \text{ watts.}$$

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The current flowing *in and out* of the condenser is, as before, 0·94 amp (the current taking the leakage path is negligible compared to this, but to be exact would have to be added vectorially) so the E.R. is

$$\frac{\text{watts lost}}{\text{current squared}} = \frac{18 \times 10^{-6}}{0{\cdot}94} = 20{\cdot}4 \times 10^{-6} \text{ ohm.}$$

This, of course, is a trifling amount. It must be observed, however, that at much lower frequencies the "condenser" current would be much lower, and the E.R. would accordingly be higher, so that leakage is of greater

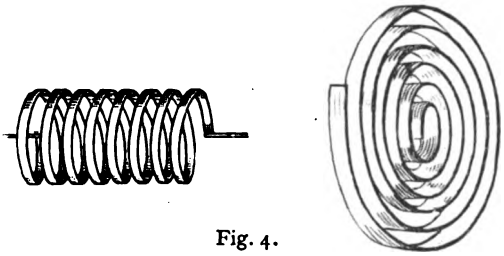

Fig. 4.

importance at low frequencies, till at zero frequency it is the only current. The resistance due to the plates, leads, connections, etc., being in series and carrying the main current is of great importance at very high frequencies, and is zero at zero frequency. The dielectric hysteresis loss, usually the most important, decreases with frequency. The moral of this is that where condensers are used at very high frequencies, such as in short wave transmitters and receivers, the metallic resistance should be kept to a minimum, while in the case of condensers used at low frequency, such as in smoothing systems, the dielectric is most likely to cause inefficiency.

The E.R. of an inductance includes quantities corresponding to the three mentioned in condensers; there is the leakage across the coil, which is usually negligible except at very high frequencies, when high voltages may be set up across the terminals; the series resistance, which is usually important, especially at low frequencies; and the hysteresis loss, which only takes place when a magnetic material, principally iron, is used for a core. In addition, there is the eddy-current loss in the core, if any, in the copper or other winding, and in conducting materials such as screws, frames, etc., in the magnetic field. The coil has self-capacity, and this gives rise to losses as mentioned in connection with condensers. The skin-effect is much greater for coils than for straight wires, and the increase in resistance due to this alone may amount to hundreds of times at radio frequencies. There may also be losses due to other coils inductively coupled. All these quantities increase with frequency, except that there is an apparent decrease in the loss caused by an iron core, due to the surface only of the iron being magnetised. All these effects may be lumped together and called the E.R. It is not practicable to calculate the E.R., but it may be measured by substitution, or by measurement of the power loss. As the loss is usually much greater than in a condenser, the objection to the latter method previously given does not apply to the same extent. An objection that does apply is that it is no easy matter to measure the power at very high frequencies, and some indirect method must be adopted, such as measurement of the heat generated. The substitution method was described in EXPERIMENTAL WIRELESS for March, 1924.

To reduce the E.R. of coils used at frequencies such as that of 100 metres the conductor is of the form of copper strip, wound as in Fig. 4, which shows a solenoid and a helix in section. The writer has seen transmitter coils wound with great trouble so that the strip lies with its edges in and out, instead of with its flat faces in and out, as in Fig. 4. Anything worse could not be imagined, as the current is only carried by the inner edge of the strip, and the bulk of the metal is practically useless. The coil should be wound on a highly insulating frame containing as little material of any sort as possible, as insulators give rise to dielectric losses and act as conductors to eddy-current losses. Prof. Morecroft gives an instance of a coil of which a terminal was fastened to the end piece with small iron screws. After the coil had been switched on for some time the loss in the screws was so high that they burnt themselves free.

The E.R. of a coil is increased by coupling another coil to it, such as in a coupled transmitter or receiver, and the lower the resistance of the coupled coil the higher the increase in E.R., because currents are caused to flow in the neighbouring circuit, and these cause losses which must be supplied by induction. The increase in E.R. is very great when the

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coupled circuit is tuned to the working frequency. Examples of this are constantly occurring both in transmission and reception. If in a coupled transmitter there are ammeters in both the closed and aerial circuits, the reading of the former will drop from perhaps 10 amperes to 2 or 3 when the aerial circuit is brought into tune.

In circuits containing both inductance and capacity it often happens that a reduction in O.R. increases the E.R. This is so in the well-known "tuned anode" amplifier coupling. Here we have L and C in parallel, and when in tune to a particular frequency the E.R. *at that frequency* would be infinitely great if the O.R. were zero. The merit of this coupling is that the D.C. resistance is very low, so no extra anode battery is required, but the resistance to the frequency to be amplified is very high. In dealing with resonant circuits there are always two points of view: series and parallel. In Fig. 5, showing the simple LC circuit, L is both in parallel and in series with C, but at the resonant frequency E.R. is infinity or zero according to the way it is considered.

If an alternator generating the resonant frequency is connected, as in Fig. 6, no current will flow, E.R. being infinity, but an infinitely large current will circulate between L and C, the E.R. that way being zero. As resistance is always present in practice, "infinite" becomes "large" and "zero" becomes "small." The main point is that at resonance the LCR circuit may be substituted by one consisting only of R; large for parallel, small for series.

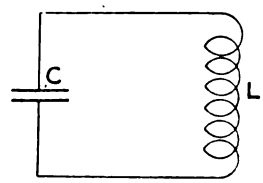

Fig. 5.

It should be noted that while in the case of series resonance, the resistance has no effect on the resonant frequency, the latter being always

$$\frac{1}{2\pi\sqrt{LC}};$$

in parallel resonance the frequency is affected by the resistance, and the formula is more complex—

$$f = \frac{1}{2\pi}\sqrt{\frac{L - R_l^2C}{L^2C - R_l^2C^2L}}$$

There is one sort of resistance which has not yet been mentioned: radiation resistance. That this seems to give rise to some trouble is shown by the fact that many experimental transmitters make a fetish of large aerial currents and seem forgetful of the fact that if such large currents are obtained by decreasing the radiation resistance, the actual power radiated may be smaller than before. The power radiated is I^2R_r watts, just as the power converted into heat is I^2R_0, where R_r and R_0 are radiation ohmic resistance. The two together (E.R.) multiplied by the current squared gives the electrical power permanently disappearing from the circuit. The only two factors materially affecting the radiation resistance are the dimensions of the circuit and the frequency. A circuit with large dimensions, such as an aerial system, has a large radiation resistance, while the latter is also proportional to the square of the frequency. The efficiency of the aerial system is

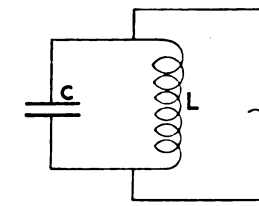

Fig. 6.

$$\frac{R_r}{R_e}$$

where R_e includes R_r and all the sources of loss, which together may be called R_l. If an aerial has a total E.R. of 15 ohms, and there is an aerial current of 10 amps, the energy in the aerial is $10^2 \times 15$ or $1\frac{1}{2}$ kilowatts. If the R_r is 5 ohms, the radiation is $10^2 \times 5$ or $\frac{1}{2}$ kilowatt, and the efficiency is $33\frac{1}{3}$ per cent.

In conclusion, this subject is so related to all the other principles of A.C. work that it is very easy to draw it out to an unreasonable length. Details are not given therefore of all the varied measurements and calculations involved, but it is hoped that this brief outline may be of assistance to some who are experiencing difficulty in passing from D.C. to H.F.A.C.

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Erecting a 100-Foot Mast.

By W. J. Turberville-Crewe. **[R320·8**

Our contributor finds the erection of a 100-ft. mast an easy matter. But we would not advise readers to approach it too light heartedly if they have had no previous experience. Many such jobs are easy to those who know how, but require thought when tackled for the first time.

WITH the arrival of winter and the consequent reduction in the strength of atmospherics, many of us are overhauling our apparatus with a view to obtaining the last ounce of efficiency; and in that respect we must not forget our long-suffering aerials. Every ten feet that can be added to the effective height of an aerial is equal to pressing into service an additional valve and, in the long run, materially cuts down working expenses.

Many people, however, fight shy of tackling the erection of any mast much above 30 ft., whereas, providing the best method is employed, a 100-footer can almost as easily be placed in position and made to stop there.

A mast four inches square at the base and tapering to four inches by two inches at the truck, constructed from pine and properly guyed, makes a very stately and imposing erection. Moreover, it will stand any weather, even a hurricane, and support the heaviest standard type of aerial up to the extreme P.M.G. limits.

It is the purpose of this article to describe in detail how to make and erect a 100-ft. mast satisfactorily.

Five 20 ft. and one 24 ft. lengths of 4 ins. by 2 ins. pine as free from knots as possible are procured from a timber yard and carefully creosoted. A dozen hexagon-head $\frac{1}{4}$ in. by 5 ins. bolts and nuts with washers should also be purchased, together with twelve steel plates 4 ins. by 12 ins. by $\frac{3}{16}$ in. thick, each being drilled with two $\frac{1}{4}$ in. clearance holes—one $2\frac{1}{2}$ ins. from either end. These will form the clamping plates for bolting the sections firmly in position.

Four 2 ft. 6 ins. lengths of good, hard wood, preferably steel shod, will be required for ground posts to which to anchor the guy wires, and these should also be heavily creosoted or tarred.

A coil of galvanised stranded wire rope to take a "breaking strain" of about 1 cwt. will serve for the guy wire, and with it a supply of galvanised straining screws or turnbuckles for making final adjustments.

Having well creosoted all the lengths of timber, the 24-footer is selected and a platform about a yard square is constructed and fitted to one end (see Figs. 1 and 3). A hole, say 5 ins. square, is cut in the platform at the point where it touches the timber, and through this guide-slot all the other sections will have to be passed in turn.

Next, dig a hole 3 ft 6 ins. in depth to receive the base of the mast, and, taking a radial measurement of 18 ft., mark out the position of the ground posts as illustrated in Fig. 2. These posts should then be driven well into the ground at an angle, great care being taken to see that they are perfectly firm, for if one of them became loose under the strain of the mast, the position would be serious.

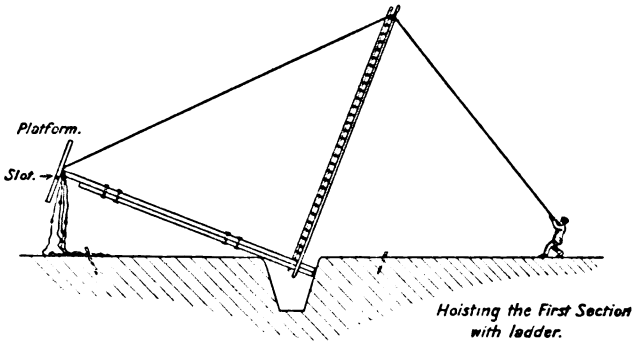

Fig. 1.

With two sets of bolts and plates one of the 20 ft. lengths is then bolted to the first on the same side as that from which the platform projects. The top of the second length should be one foot below the platform (see Fig. 3). The reason for this will be seen later.

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The first, or "stub" section, 4 ins. square, is now ready for erection, and the first set of guy wires must be attached. With the aid of a ladder, proceed to hoist this stub into position as illustrated in Fig. 1, and, having securely guyed it, fill up the hole in the ground with concrete. The latter, by the way, *must* be allowed to set before proceeding further.

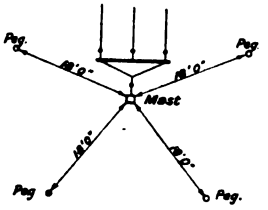


Fig. 2.

If one part of Portland cement and three parts sharp sand (obtainable from any builder) are thoroughly mixed together dry and afterwards sufficient water is added and the mixture stirred with a shovel into a good thick paste (not too sloppy) this will set in a few hours after pouring into the hole.

The aerial pulley is then attached to a further 20 ft. length and a cap nailed on to prevent the wet from running into the grain of the wood. After that the length is pushed through the hole in the platform, the bottom end resting on the ground, and a set of guy wires attached to the top end by an assistant who has climbed to the platform by means of the ladder, which is now lying idle. A pulley is secured underneath the platform, and by its aid the section can be hauled up from the ground and temporarily guyed to steady it.

Next raise another length of timber on end against the stub and bolt the top of it to the bottom of the length just hoisted. Lower the hauling rope to the lower section, and the mast is raised another 20 ft.

An important thing to remember at this point is that the first section that is hauled up becomes the top section of the completed mast—all the intervening lengths being securely bolted to the bottom of the last one and hauled up whilst their lower ends are resting on the ground.

When the four upper sections have been bolted together and hoisted in this manner, the bottom of the last section hauled up will rest upon the top of the shorter timber of the stub section. The reason for leaving the foot overlap is now seen, for it is to this overlap that the bottom of the second section is now bolted.

It will be noted that throughout the operation the hole in the platform acts as a guide slot, steadying the sections as they rise.

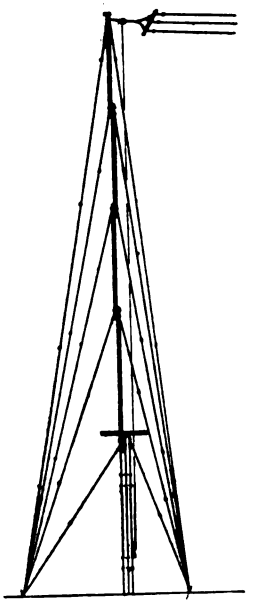
The whole secret of the stability of the completed mast lies in the rigging of the guy wires, and it will be found that a set of guys will be needed at every joint from the platform level upwards (see Fig. 3). Staying chocks, made by screwing pieces of wood to the mast, should be used at every point where the guy wires are secured. These chocks should be fitted as shown in Fig. 4.

The guy wires should be fitted with insulators at intervals of 20 ft., particularly is this advisable if the aerial is to be used for transmitting purposes, as otherwise trouble from harmonics will usually manifest itself.

The question of a stable aerial and lead-in that will not sway in the breeze has caused a sleepless night to many an earnest experimenter. Nothing is more annoying than having continuously to swing the condenser in attempted synchronism with the sway of the aerial in order to hold a distant station.

If the aerial is tensioned up to the last ounce of pull on a warm, dry day, and contraction ensues with a fall in temperature, or rope halyards shrink under the influence of damp weather, something has to go —and it is usually the aerial!

A very simple expedient will overcome these exasperating difficulties, however. Instead of securing the halyards to a cleat on the mast, why not rig up a counterweight running in a guide? Everyone is familiar with



The completed mast.

Fig. 3.

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the weights used on lifts to balance them, yet I have rarely seen the principle applied to the aerial. If the weight is selected with a little care it will keep the aerial steady under all conditions, and any unexpected, abnormal tension will be automatically compensated by the rising of the weight.

An idea of the completed mast is shown in Fig. 3.

It is advisable to secure the assistance of at least five friends—one to stand at each ground post and feed out the guys as the mast rises, and another to bolt sections together and attach guys as they come up through the platform. The owner can then remain at the foot of the mast and do the necessary hauling and control operations.

The principles of construction and erection will hold good for a mast of any reasonable height provided the at the guy wires, thick-ness of the mast-sections and the radial measurements to the ground posts are all increased in direct proportion.

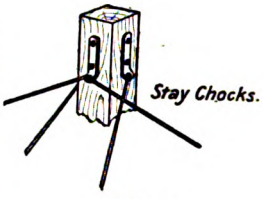
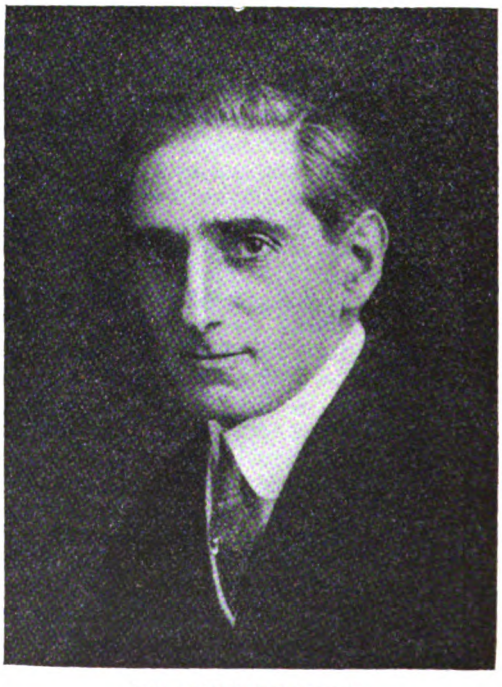


Fig. 4.

The Change at Marconi House.

[R097

MR. KELLAWAY.


MR. GODFREY ISAACS.

Mr. Godfrey Isaacs, whose name has long been a household word among our readers in connection with his onerous duties as Managing Director of the great Marconi undertaking, has been forced by ill-health to resign.

Mr. Kellaway, who will be remembered as a recent P.M.G., and still more recently as a Director at Marconi House, has taken Mr. Isaacs' place.

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The Perfect Set.

Part III: L.F. Amplification. [R342·7

Unfortunately, this subject is too large to be covered in the available space. Below we deal with the valve: a later part will be devoted to the intervalve coupling.

IT may seem illogical at first glance that we should call this part of our series "L.F. Amplification" instead of "The L.F. Amplifier." But the principles underlying amplification are essentially the same in single- and multi-valve amplifiers. In describing a single stage, while specifying the differences between various stages, it is possible to cover the whole ground.

Right at the beginning, however, one must distinguish clearly between amplifying morse and telephony. It is hardly necessary to labour the point, but one may as well state formally that in the first case we are only interested in amplifying one particular note, so that "note tuning" or audio-frequency selectivity is an advantage and high amplification the desideratum; in the case of telephony we desire beyond everything distortionless working, *i.e.*, even amplification of all audible frequencies (or in some cases a known deviation from this) and high amplification may have to be sacrificed.

We will consider first the question of telephony, for it is in this branch that there is the most immediate need.

Now a stage of amplification essentially includes two separate devices: the valve (with its supply for filament, etc.) and the intervalve coupling. It is the fashion at present to concentrate attention on the coupling, which is an excellent thing, but must not tempt one to neglect the study of the valve. For this reason we shall take the valve first.

It is hardly necessary, even in a fairly elementary article, to go into the question of how a valve amplifies. We believe that all our readers already realise that if the output is to be a faithful reproduction of the input, the grid volts must never go on to either the upper or lower bend of the valve curve; *e.g.*, if the characteristic of the valve under the conditions of working is as shown in Fig. 1, the input must not make the grid go beyond +2 or −2 volts.

But the second condition for faithful amplification is even now not so fully realised. *Grid current must be prevented.* When the grid is so negative that there is no grid current, the valve behaves towards the input like a very small condenser. It offers a reactance of the order of several megohms to currents of audible frequency. If, during the positive swing of the input voltage, the grid becomes too positive, the valve acts like a condenser and resistance in parallel, and may offer only a hundred thousand ohms or so. The effect is much like that of putting a "short" on the domestic lighting supply—down come the volts with a rush. In this case that means a loss in amplification. But this resistance of "a hundred thousand ohms or so" is not

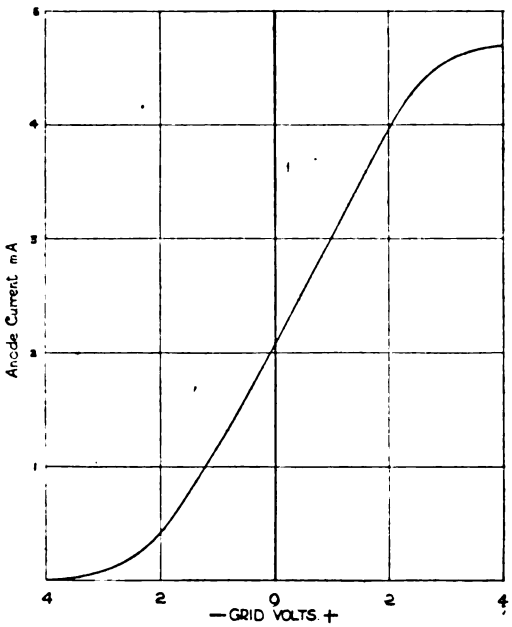

Fig. 1.

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constant, but varies during each cycle of input. Hence the amplification is uneven, and distortion is introduced.

There is just one, and only one, way of avoiding this trouble, and that is *grid bias.* To us, a valve without bias is like an egg without salt, or—to use the mid-Victorian maiden's simile—a kiss without a moustache: the result has not the taste of the real thing.

In considering this question, we open up the whole question of the correct three voltages—anode, grid, and filament—for any valve. The usual method of settling these, as far as we can make out, is to use rather less than the maker's rated filament heat (to get long life), and then to apply whatever anode volts are available, and put on any grid voltage fancied. In actual

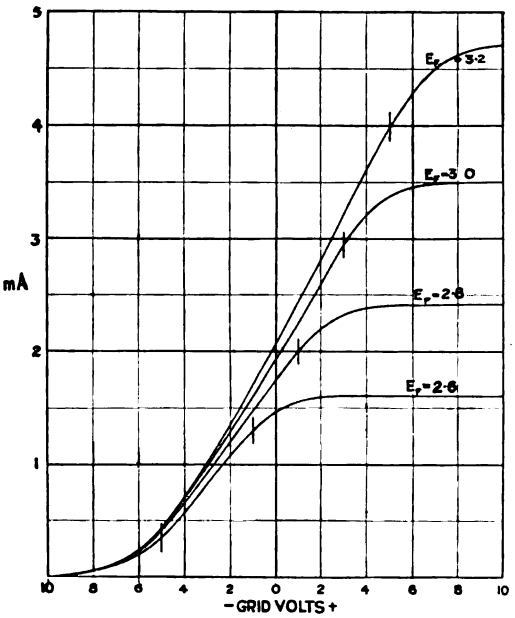

Fig. 2.

practice, one can make very definite specifications for all three, if one has proper information, to wit, full valve characteristics and a knowledge of the input voltage (of which more anon).

Filament Heat.

In every case, the first consideration is the minimum filament heat. An increase does no harm to amplification, but shortens the valve's life. Fig. 2 shows curves for a French valve of the 60mA type at various filament voltages, with 100 volts on the anode in each case. There is a rapid increase in saturation current, but, more important, a much greater permissible input. In each case, the grid must not go below about — 5 volts. But increase of filament heat enables us to extend the range of — 5 to — 1 (4 volts "swing") in one case to a range of — 5 to +5 (10 volts "swing") at the largest filament heat shown. In practice, as hinted above, we shall see that the grid stays negative, but, as is shown below, that does not affect the total "swing" obtainable.

Our rule for filament heat, then, is simple (in theory): *The minimum filament heat is that which allows the required input swing on the "straight" of the valve curve.*

In practice, what is the input? This is the crux of the whole question, and is not yet widely known. The real difficulty is to get a good definition. Suppose we give the input to the last valve for "good loud-speaker strength," what will our readers understand by it? In further detail, our idea of this is that the announcer speaks very loudly; the soloist is a little below his actual strength in the studio; the orchestra considerably less than its original strength (the difference arises, of course, in the control room, where the input to the transmitter is cut down for loud performances). Most of the programme can be *heard* all over a four-storey house if the room door is open: it can be *understood* one floor up or down. The input to our last valve has an amplitude (measured) of about 7 or 8 volts, *i.e.*, a swing of 15 volts. This figure is the same as that given by Capt. Eckersley as "probable for good loud-speaker work in a fair-sized room," and tallies with that in last month's E.W. & W.E., as measured by G. W. Sutton (E.W. & W.E., Nov., 1924, p. 92). From it one can find the probable input for other stages.

The other question is as to the output of the valve (or rather its maximum safe input) at different filament heats. Unfortunately it is comparatively rare that this information is given. Our own test reports do so, and we show elsewhere in this issue how to convert the condensed curves we show into the ordinary form. It is just as well to repeat here that the effect of increasing anode volts is as if the curve were shifted toward the left. There is not an increase of saturation

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current (there may be a small increase in some cases, but not a *working* increase).

Going back to our curves of Fig. 2, we see that this valve, even at 3·2 volts, will only give 10 volts swing, and will, therefore, not give "good loud-speaker strength" without distortion. But if it is used as the last valve but one, resistance coupled, we can estimate its input swing as, say, 2 volts; for it happens to give a magnification of 10, so that with resistance coupling it would give an amplification over the whole stage of, say, 7 to 8, so that 2 volts on it would give 15 on the last stage.

This swing of 2 volts can quite easily be handled by this valve, even at only 2·6 volts. But since the curve at that filament heat is not a particularly nicely shaped one, it will probably be better to use 2·8 volts.

Grid Voltage.

Next, the grid bias. Our condition is that there shall be no grid current. It is frequently assumed that this will be avoided if the grid never becomes positive compared to the negative end of the filament. But this is not quite correct. Different valves have different "thresholds," as it were: within the common range of receiving valves are some where grid current begins at — 2 volts on the grid, and others where there is none till the grid reaches +2 volts. In the absence of a curve or other definite information, it is fairly safe to call — 1 volt the limit.

If now the *most positive* value of grid volts is to be — 1, the steady voltage must obviously be half the swing below — 1, *i.e.*, for the last valve it must be — 8½ at least; for the last but one, with a swing of 2 volts, it must be 1 volt below — 1, which is — 2.

This is quite simple: the main point to grasp is that the least desirable grid bias is fixed, not in a laudable attempt to keep down anode current with a given anode voltage, but is given by the input before the anode voltage is decided.

Anode Voltage.

This again is quite easy. Knowing the grid bias and the input swing, we know the limits between which the grid volts will vary. All that is necessary is to apply such anode volts that between these limits the characteristic is straight.

Thus, suppose we are using for last stage the power valve whose curves are shown in Fig. 3. We see that the requirements are fulfilled by an anode voltage of 160. We could use a higher anode voltage if desired, with a larger grid voltage, such as 200 on anode and — 15 on grid, but this has no advantage so long as we are beyond the minimum values found as indicated.

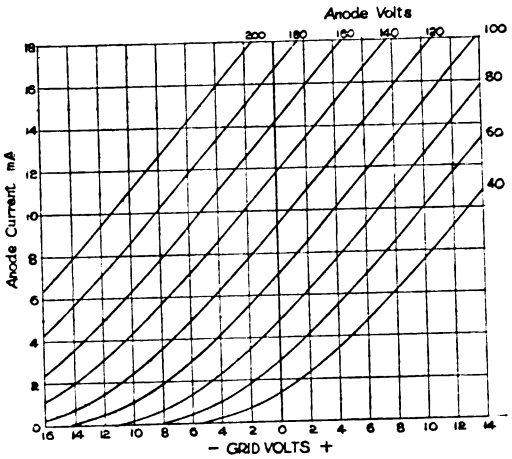

Fig. 3.

Summarising, our rules for valve adjustments are:—

First.—See that the filament volts are enough to handle the input on the straight part of the curve;

Second.—Set the grid bias to at least one volt more than half the swing;

Last.—Use sufficient anode volts to bring the centre of the straight part to the grid bias already found.

It will be remembered that we divided the subject of L.F. work into morse and telephony, and then divided a stage into the valve and the coupling. We have now (we hope) given some idea of how the valve should be treated. We have next to examine the coupling, and then consider what modifications we shall make when our object is not distortionless telephony work, but high efficiency for morse. But space is short, and we must defer these parts of our subject till next month.

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Radio 5KO. An Amateur Station.

By T. W. Higgs, B.Sc.(Eng.). **[R612**

DESPITE that the old call sign 5KO is heard no more on the air, many people will read about the station with interest.

The receiving side, of course, has been in existence for years, in various forms, alternately at Bristol and Wolverhampton, and at both places simultaneously. Transmission, however, was not commenced until January, 1923, when the call sign 5KO was allotted and the station appeared on 440 metres, C.W. and telephony.

A few weeks of this proved quite enough to arouse the hatred of every broadcast enthusiast for miles around Bristol, so a descent was made to 200 metres, in the vain hope that this would settle the quarrel. There followed the usual wild search for vanished aerial current, the erection of counterpoises, and all the struggles involved in a first attempt at short-wave transmission, until, at the end of March, 1923, we were proudly putting half an ampère into the aerial and had worked with F8AB—the Ultima Thule in those far-off days.

In spite of QRN and the periodic collapse of the aerial, the summer passed pleasantly enough, the efficiency of the set being gradually increased; and in May, our faithful friend, Mr. Steffensen, reported 5KO's telegraphy in Denmark, and shortly afterwards succeeded in hearing weak speech from the station. At about this time the circuit, after much dabbling in "reversed feed-backs," Colpitts, etc., finally settled into the Hartley, and the aerial current reached the delightful figure of 0·9 ampère with 10 watts input. Theorists have claimed that 1·2 amps can be reached, but although the writer has actually seen this obtained, he is doubtful whether the average amateur station can honestly claim to come anywhere near it.

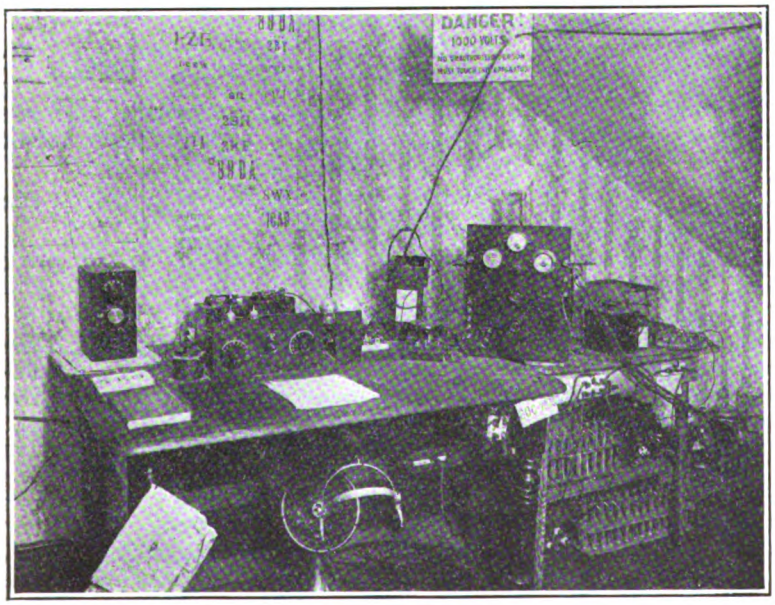

Fig. 1.—A general view of 5KO's station.

Towards the end of the summer the Transatlantic tests began to loom large on

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the horizon, and after a careful review of finances, for this was not a millionaire station, an application was made for a 200-watt licence. The remainder of the year was spent in writing letters inquiring when the said licence might be expected to materialise. It finally arrived in the nick of time, and since the amateur radio enthusiast is nothing if not optimistic, all the apparatus was in readiness.

In the meantime the receiver had been somewhat improved, and persuaded to tune down to 100 metres and under, and we had the surprise of our lives when the first two stations we logged on these waves turned out to be F8AB and U1MO engaged in friendly conversation—the first we had heard of the actual accomplishment of amateur two-way work across the Atlantic.

At 1 a.m. on the morning of December 22, with two 50-watters in the sockets, an attempt was made at the first code group; the key was pressed and the aerial ammeter crawled over to 3 amps. Note to beginners: Never try to key in the aerial circuit when there are three ampères in it. . . .

A new key was next placed in a less "juicy" part of the transmitter, and a fresh start made. The first five 50-watt valves proved soft, and it will readily be imagined that they did not turn more blue than did the air around the "den" after the operator had made his comments on the situation. As a consequence we had to fall back on two trusty Mullard 30's, and the rest of the tests, and all our subsequent two-way work, were carried out with these two long-suffering valves, the input to the two in parallel being around 50 watts.

The first report received was from 3APV of Washington, who logged the code DZWWT correctly on December 27. From this time until the end of April frequent two-way work was carried on—sixteen American and four Canadian stations being worked—while the signals were reported in the 1st, 2nd, 3rd, 4th, 8th and 9th U.S. districts and in the first three Canadian districts, the farthest being BX and 9AKE. After April the approach of a final examination caused a slackening off in early morning activities, though Argentine CB8 was logged on the morning of May 25. At the end of June, examinations being over, Finnish 2NM was worked, and in early July the station was closed down owing to the owner's removal to Newcastle-on-Tyne.

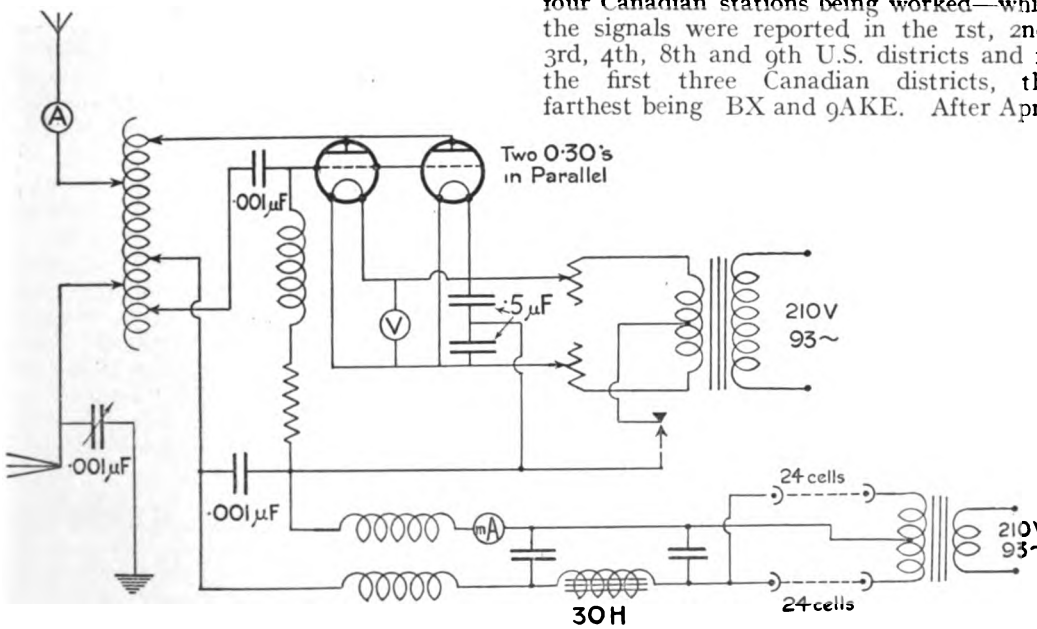

Fig. 2.—A Circuit diagram of 5KO's apparatus.

During practically the whole of this work, the circuit used was the Hartley, with series supply: the H.T. was 1 000 volts of rectified A.C., and the only type of rectifier used was the electrolytic, which gave every satisfaction. They were made up in five-inch test-tubes filled with a solution of borax, 24 cells in series with each outer of

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the transformer in the usual centre-tap circuit. The filaments were supplied from an 8-volt winding on the transformer, the periodicity of the supply was 93 cycles.

A general view of the apparatus is given in Fig. 1, and a circuit diagram in Fig. 2. The aerial was a 4-wire cage 50 feet long and of an average height of 50 feet with T lead-in also caged; one end supported by a 30-foot steel tubular mast on the roof of the house, the far end on a 60-foot tree. An 8-wire counterpoise ran more or less beneath the aerial, and the earth connection was made to the zinc roof of the building, all buried earths having proven unsatisfactory owing to the length of the lead, since the "den" was in the top storey.

Two receivers were in general use—a loose-coupled tuner, with detector and one stage L.F., and a Reinartz with one L.F. The station was heard in U.S.A., Canada, W.N.P., Algeria, Finland and 13 other European countries.

For the future 5KO will be located in Newcastle-on-Tyne, at present in lodgings; but probably by the time this article appears a more settled QRA will have been found and a lady operator added to the *personnel*. Address for the present is 4, Victoria Square, Jesmond, Newcastle. Reception is still carried on, of course, but the 240-volt D.C. mains do not provide much "kick" for the transmitter, and it is hoped that the next move will be to a house equipped with A.C. mains. But the question we are asking ourselves is: "Is it worth while re-erecting the station in order to communicate *only* with stations in Great Britain and Northern Ireland?" The answer certainly seems to be in the negative.

Fault Tracing.

Diagnosing Defects without Instruments.

By L. R. Gleason. **[R620·068**

WIRELESS sets, no matter how carefully constructed, are liable at times to develop faults. This in no way reflects on the skill of the designer or workman, for the fault is usually due to fair wear and tear. Sometimes the hand of the user, not always well-trained in the delicate adjustments of control, is the main cause of the trouble. In all cases it is well to be able to remedy speedily minor defects which have the annoying property of turning up exactly at the wrong moment.

To have a sound knowledge of a receiving set is always of value to the operator, but the fullest knowledge can only be obtained by the actual construction of the set. When this is not possible it is at least useful to have a swift means of diagnosing the cause of the trouble.

It has been said that a little knowledge is dangerous. Probably this is quite true, but it is by no means so dangerous as the unskilled investigator armed with a screw-driver and in a hurry to remedy a fault.

Apart from a dull spot on a crystal, a burnt-out valve or a valve fitted with plugs that do not make good contact with the sockets, the majority of faults are due to broken or imperfect connections, and if the latter there are none more irritating than an intermittent disconnection.

We do not pretend in this article to give a method of measuring the capacity of condensers or the resistance of transformers or grid-leaks. The principal object is to provide a simple means by which a circuit can be tested when a defect develops and, in the case of a home-made set, the connections

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tested and checked without stripping the set down.

It cannot be emphasised too strongly that, in seeking for a fault, the only swift and sure method is to use a definite system. Without this all efforts are haphazard. The systematic method is employed by all large telephone and telegraph concerns and by the maintenance engineers of intercommunication telephone companies.

The principal feature of the system is that no instruments are necessary and that the set itself provides the requisite means for making an adequate test. Every receiving set is fitted with at least one headphone, and this, allied to the ear of the user, furnishes a means of testing that can hardly be surpassed by even a very sensitive galvanometer.

Systematic Testing.

Fig. 1 is a diagram of the internal connections of the familiar G.P.O. telephone. It will be seen that there is normally a D.C. voltage of about 22 across the lines connecting with the Exchange. So long as the receiver is on the hook, no D.C. current passes through the instrument. For our purpose a fault now arises and to locate it we possess only a headphone. Simply with this, the fault can be traced, and the same system applies to wireless sets; transmitting or receiving; large or small.

We will assume that on attempting to call the Exchange no reply is received. Replace the receiver on the hook and proceed as follows. Connect the headphones across the terminals B and C (Fig. 1). A loud click will show that the line to the exchange is intact. If none is heard the line is broken, or the lightning arrester has

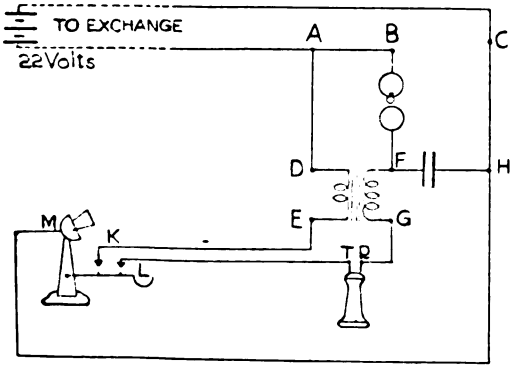

Fig. 1.

been in action. A dead short circuit in the condenser between F and H is also a possible but unlikely fault. Leave one of the headphone cords connected to C and with the tag of the free one make the following contacts, A, D, E, K, L, T, R, G, F. In each case a click should be heard. If not, the fault lies between the last point giving a click and the silent point.

For example, a click at F shows that the bell coils are unbroken; similarly a click at G indicates that the secondary of the induction coil is intact. A silent point at R indicates that there is a break in that particular lead of the receiver (G R). Now disconnect the lead of the headphone from C and connect to B. A loud click on touching F indicates a short-circuited condenser, while a click at point M proves that the circuit between the microphone and the line wire is complete.

There are many other tests that will suggest themselves to the reader, but as telephone testing alone is not the purpose of this article, it is sufficient to indicate the working of the method.

Application to Wireless.

To come now to the application to wireless sets. Fig. 2 is a diagram of a crystal set which we will assume has suddenly become silent. In this case a small battery is a convenience and one of the ordinary pocket flash-lamp type is quite suitable. Disconnect the telephones and first make sure that *they* are all right by connecting them across a battery. A loud click should result and no uncertain crackling sounds be heard as the cord is run through tightly gripped fingers. The cord, by the way, is very frequently the culprit. If no battery is available, a small pile of silver and copper coins placed alternately and moistened with vinegar will provide enough current to test the phones.

After making certain that the *outside* connection of the aerial to the lead-in is sound, connect the headphones in series with the battery and after removing the crystal, apply one lead to A. A click on touching E shows that both coils of the variometer are in order: silence at E would prove a break in one or other of the coils.

Failure to obtain a click on touching the top of the crystal holder at B proves the fault to lie between it and A.

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Next disconnect the telephone lead from A and connect to E and prove E P. A loud click on touching H indicates a short circuit in or across the condenser.

It will be seen that all the above tests can be made without removing a single screw.

The case of a valve set (Fig. 3) is just as simple and is facilitated by batteries being available. First remove the valve; then disconnect the headphones and prove them as described. Then connect them in series with the L.T. battery, which should be disconnected from the set. The H.T. battery should also be unplugged. A click between A and E shows that the ATI is in order, but if it is of the type varied by a switch

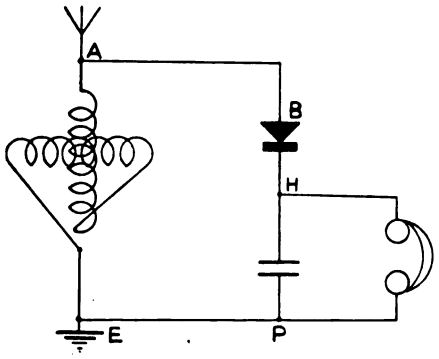

Fig. 2.

and a number of tappings to studs, each of these should be tested. This can be done rapidly and will often show that although the ATI as a whole is intact, a silent stud proves a break in that particular tapping.

The reactance is tested by touching the terminal P with one lead and the plate socket in the valve-holder with the other. No crackling sounds should be heard while the reactance is rotated or varied. A very loud click between A and G (the grid socket in the valve-holder) points to a shorted grid-leak or condenser, which should be removed and tested separately. Similarly a loud click between M and K indicates a short circuit in the telephone condenser. Particular care should be taken in testing between points B and S. The valve should be replaced before making this test and the filament resistance manipulated to ascertain if there is any uncertain contact between the switch-arm and the resistance-spiral.

As in the case of the crystal set, all these tests—with the exception of removing the grid-leak condenser—can be made with speed and ease without opening up the set.

The same system can be applied to a

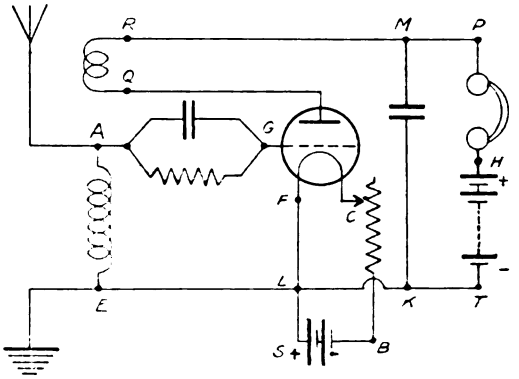

Fig. 3.

multi-valve set provided that the person testing will adhere to a definite routine and observe the golden rule of beginning at the beginning and suspecting every part of the circuit until it has been proved clear of doubtful or intermittent continuity. Tapping the apparatus with a pencil or the knuckles while listening during the various tests will often disclose, by the rustling sounds caused, an intermittent contact that otherwise would remain an elusive nuisance.

Volume I. of E.W. and W.E.

Our publishers ask us to state that arrangements have now been made with regard to Volume I. of EXPERIMENTAL WIRELESS AND THE WIRELESS ENGINEER.

Binding cases (with index) are ready, and can be supplied at 3s. 3d. Readers may, if desired, forward their numbers and have them bound, the inclusive charge for this being 8s. 3d. Lastly, we have a few complete bound volumes available for sale at £1. These are illustrated on page 189 in this issue.

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Cumulative Grid and Anode Current Rectification. [R134

By H. J. Barton Chapple, Wh.Sch., B.Sc. (Hons. Lond.), A.C.G.I., D.I.C.

The writer gives the results of some quantitative tests, showing the degree of rectification obtained with various values of grid resistance, grid and anode voltages.

THE object of these experiments, carried out in the High Frequency Laboratory, Bradford Technical College, was to obtain quantitative data for reference when employing the thermionic valve as a rectifier.

The principles involved in cumulative grid, or—as it is sometimes called—grid-current, rectification, and also anode current rectification are fairly well known, but a brief reference to the mode of operation will not be out of place here.

Referring to Fig. 1—which indicates a simple single valve receiver arranged for cumulative grid rectification—and omitting for the moment the grid-leak resistance R, if the filament is incandescent, the grid will assume a slightly negative potential—just sufficient to repel further electrons from accumulating on the right hand side of C, which, of course, acts as an insulator. This potential is generally about —1·5 volts.

When the received signal produces oscillations in the L_1C_1 circuit, the grid is made alternatively positive and negative with respect to the filament, as C is a conductor to the alternating potentials. Electrons will be attracted to the grid during the positive half-cycle and, since they remain on the right hand side of C, will cause the grid to assume a higher negative potential than previously.

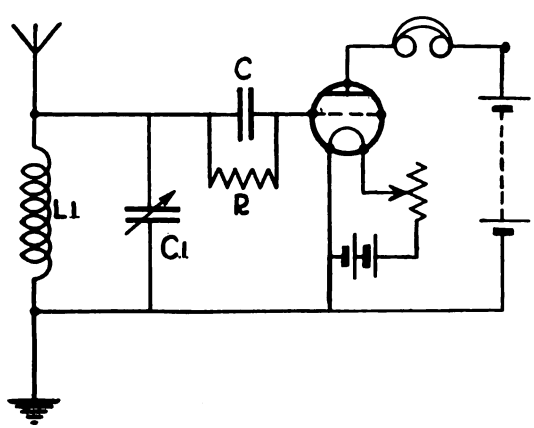

Fig. 1.

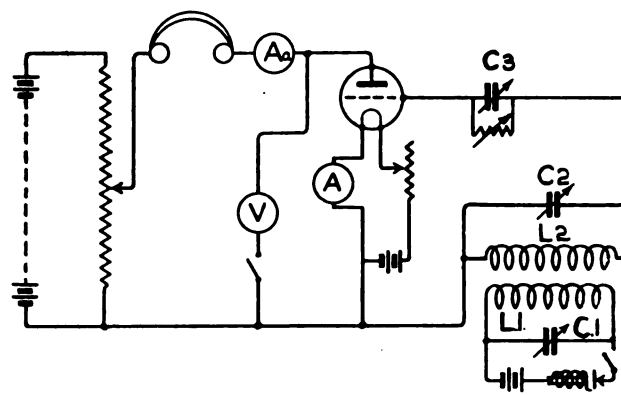

Fig. 2.

The negative half-cycle makes the grid momentarily still more negative, but no electrons are attracted. The following positive half-cycle raises the grid potential above its initial normal value, and more electrons are attracted; and so on, until at the end of a wave-train the grid will be at a relatively large negative potential. The anode current has decreased in consequence, and further wave-trains would produce little or no effect on this resulting condition.

The object of the grid-leak resistance R is thus to restore the thermionic valve to its initial condition by allowing the electrons accumulated on the right hand side of C to escape across C and travel to the filament *via* L_1. The resulting change in anode current gives the familiar telephone signals. In order to secure the maximum decrease

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in anode current for a given alteration in grid-potential the thermionic valve should be worked on the straight line portion of its particular static characteristic curve for the given anode potential.

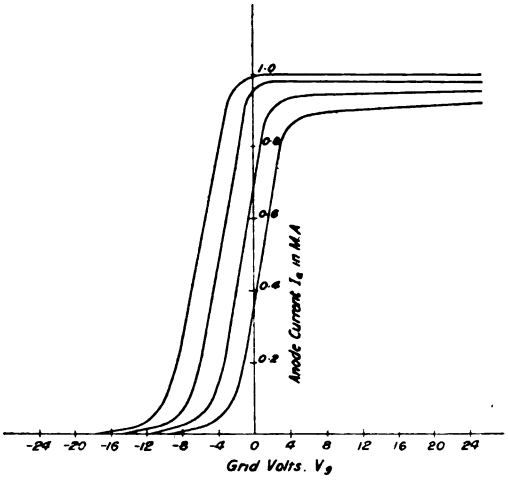

Fig. 3.

In the case of anode current rectification advantage is now taken of the bends in the static characteristic, and signals are heard in an almost identical manner to ordinary crystal rectification. For a given change of grid potential, the average resulting alteration in anode current will be an increase if working on the bottom bends, but a decrease if operating on the saturation bends.

For the purposes of this experiment, apparatus was first connected as indicated in Fig. 2. L_1C_1 is an oscillatory circuit buzzer exciter very loosely coupled to L_2C_2, which is connected to the grid of the thermionic valve through the variable grid-leak resistance R and variable air condenser C_3.

Varying potentials could be applied to the anode by the potentiometer across the H.T. battery, while to measure the anode current a sensitive unipivot micro-ammeter (A_a) was employed, shunted by a resistance box to give suitable scale deflections. A new Mullard Ora thermionic valve (F153) was used, with the filament current kept constant at 0·6 amp. Four static characteristics of this thermionic valve are shown in Fig. 3, with anode current I_a plotted against grid volts V_g for anode potentials V_a between 40 and 100 volts.

A Watmel variable grid-leak resistance was utilised for R, and, adjusting this to 1 megohm with the aid of a bridge megger, it was shunted across C_3. With C_3 set at a low value, A_a was read with the buzzer off and working, corresponding to the aerial circuit (equivalent to L_1C_1, which had been tuned to the frequency of L_2C_2) unexcited and excited by incoming signals. This was repeated for various values of C_1 up to 0·001 5 microfarad, the anode potential being kept constant at 40 volts throughout. Corresponding sets of readings were taken with V_a at 60, 80 and 100 volts, and R at 2, 3, 4 and 5MO. The change of anode current (decrease in every case) was then plotted against values of C_3, and the whole 18 curves are shown in Fig. 4.

A good deal of interesting information may be secured from an analysis of these curves, as they indicate the magnitude of signal strength to be expected with the familiar 0·0003 grid condenser, and the advantages accruing by increasing this value and also using other grid-leak resistances than the usual 2MO, with subsequent adjustments V_a. This may be best studied by turning to Fig. 5, which is plotted from

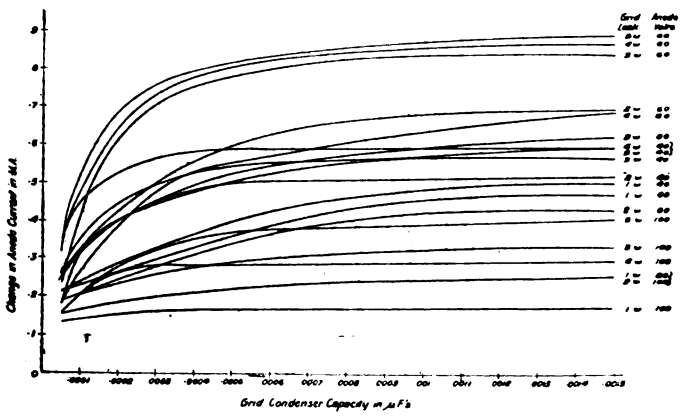

Fig. 4.

Fig. 4, with change of I_a against R for C_3 at 0·000 3 and 0·000 6μF, curves indicated by thick lines being with the latter condenser setting and by thin lines with the former.

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The results drawn for V_a=60 volts are distinctly the best, and doubling C_3 gives 25 per cent. added current change with R = 2MO and 16 per cent. with R=3MO. The advantages of 3MO and 0·000 6μF are particularly noticeable in every case, but it is seen that increasing V_a

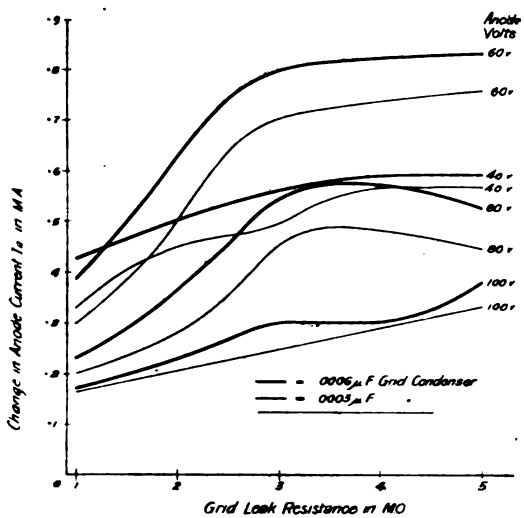

Fig. 5.

beyond 60 volts results in a reduction of signal strength. Again, increasing R to 4 or 5MO, while giving a slightly greater telephone sound with V_a at 40 and 60 volts, reduces it with V_a at 80 and 100 volts.

A further set of curves are shown in Fig. 6, which is derived from Fig. 5, with change in I_a plotted against V_a, C_3 being at 0·000 3 and 0·000 6μF as before for various values of R, while thick curves stand for the latter condenser setting and thin ones for the former. These conclusively indicate how critical is the choice of V_a in the cases of 3, 4 and 5MO, and emphasise the necessity for a careful examination of the static characteristics of a thermionic valve to ensure efficient working.

Referring to Fig. 3 it is clear that the 60-volt curve is bisected by the —1·5 grid volt ordinate, which is the normal steady working point, and thus would have been chosen in the usual circumstances, although with R at 1MO, 40 volts is slightly better than 60 volts.

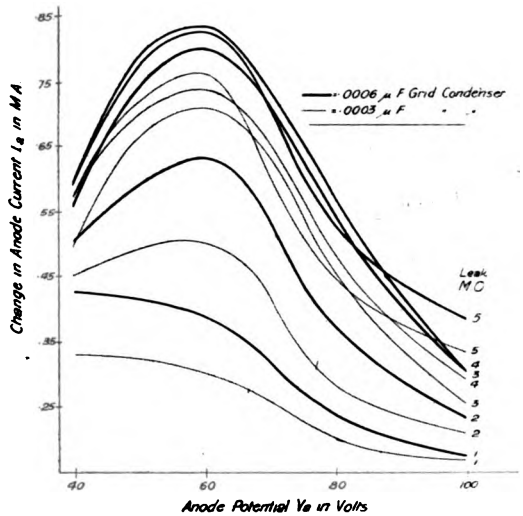

Fig. 6.

While the necessary value of V_a will depend upon the magnitude of the filament current and the type of thermionic valve employed, the results indicate that improved signal strength will be the outcome of an adjustment of R to 3MO and C_3 to 0·000 6μF. To ensure maximum efficiency both these quantities should be variable in any good receiving set, as it then permits the operator to make careful adjustments to suit particular requirements.

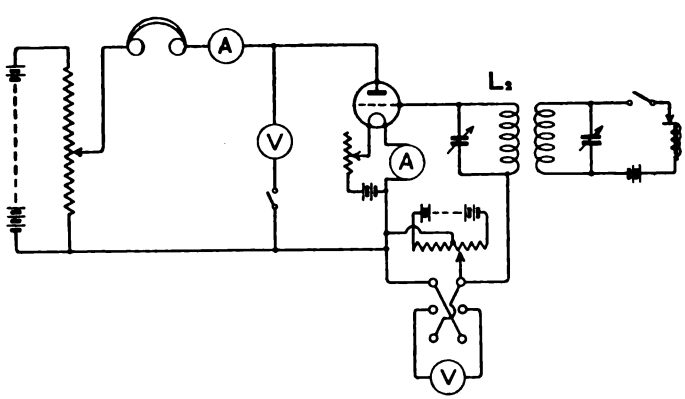

Fig. 7.

The author has found during the course of his experience that too often little attention is paid to this portion of a receiving set, although it is just as important as the tuning arrangements; and the substitution of "variables"

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for "constants," while necessitating extra care and adding to the multiplicity of the controlling factors, invariably gives ample repayment for the time spent in making the adjustments. In the case under review 0·000 6 μF. shunted by 3MO give excellent results when used in conjunction with 60 volts on the anode.

Turning attention now to the less familiar mode of rectification, viz., anode current, the circuits of Fig. 2 were modified to those shown in Fig. 7.

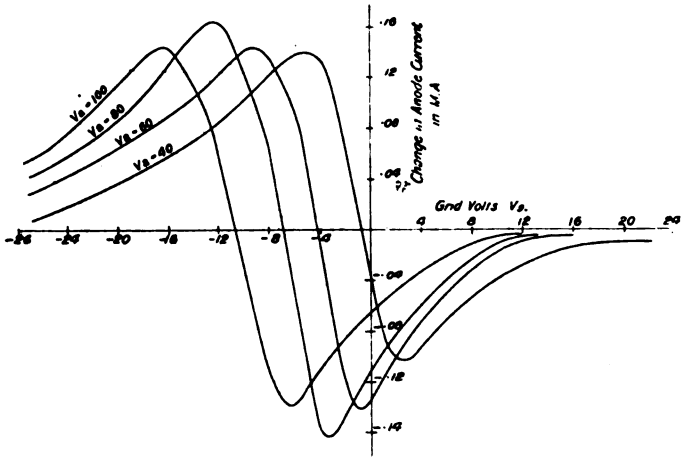

Fig. 8.

By the aid of a potentiometer across a 50-volt battery, various positive and negative potentials could be applied to the grid *via* L_2, the negative leg of the filament being permanently attached to the centre point of the potentiometer, while the free end of L_2 was connected to the movable contact as indicated.

With V_a set at 40 volts, the grid potential was adjusted to —24 volts and readings of anode current taken with the buzzer off and working. This was repeated for several values of V_g up to +24 volts, and the whole process then repeated for V_a at 60, 80 and 100 volts. The curves shown in Fig. 8 are the result of plotting V_g against the change of anode current brought about by the incoming oscillations.

With negative potentials on the grid, an increase in anode current is observed when operating on the bottom bend of the characteristic, which, of course, is what would have been expected. The resulting changes exhibit almost equal maxima for the four chosen anode potentials, and the value of V_g is seen to be fairly critical. Similar results accrue at the top characteristic bend with a rapid falling off of signal strength between bends; *i.e.*, on the straight line portion of the static characteristic.

Perhaps the most important feature to notice is that the change in anode current when employing this type of rectification is considerably smaller than with the former and more popular method, about one-fifth of the signal strength being secured under the best working conditions. Thus little doubt exists as to the more preferable mode of operation, especially as the latter method necessitates the employment of additional batteries requiring periodic charging.

The author wishes to thank Messrs. Rhodes and Sutcliffe, electrical students, for assistance in determining some of the experimental data.

A Receiver for Wave-lengths of 3 to 5 metres.

By E. H. Robinson (2VW). **[R343**

WORK on short wave-lengths of only a few metres is now attracting the attention of wireless experimenters to an increasing extent every day. In the American and French technical Press particularly articles dealing with these ultra-short wave-lengths have been appearing for some time past, but the majority of these articles only tend to show that this branch of the science is at present in a very elementary stage.

A number of ingenious transmitting circuits to operate on 5 metres or so have been devised and published, but the receiving side does not seem to have received its share of attention. This is a lamentable state of affairs, as it is of no use to us to be able to transmit on a wave-length on which we cannot receive.

In the writer's rather limited experience of short waves the question of sensitive and stable reception is a considerably more

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difficult one than that of transmission. On 100 metres the possibility of material H.F. amplification is open to question; on 4 metres it is right out of the question. The present state of the art therefore offers only three alternatives, namely, the plain regenerative detector valve, the supersonic heterodyne or the Armstrong super-regenerative detector. All three involve as a starting-point a good one-valve regenerative receiver, and a brief description of a one-valve receiver forms the subject of the present article.

Figs. 1 and 2 between them should give the reader a pretty clear idea of the writer's receiver, which was constructed for work on about 3-5 metres. Fig. 1 gives details, while Fig. 2 is a perspective sketch of the whole assembly. Absolute simplicity is desirable, so it was decided to use a Hartley circuit, with one simple solid oscillatory circuit.

A stout ring (A) of copper bar (both Figs.) has a gap in it, the free ends being soldered to two parallel copper plates (B and C). A forms an inductance of one turn, while B and C form the plates of the tuning condenser. The ring A is stiff and springy, and tends to hold the plates B and C apart, while an opposing screw action (illustrated at J in Fig. 1) enables the plates to be pushed together to a greater or less extent by rotating the insulated arm H. This constitutes the means of tuning the circuit.

By means of flexible leads as short as possible, plates B and C are connected to grid and anode respectively. The beauty of the Hartley circuit, which few people seem to appreciate, is that it has little or no mean H.F. potential to surrounding bodies, and has a nodal point somewhere in the middle of its inductance. The former fact tends to reduce stray dielectric losses and the latter fact has been utilised by suspending the whole circuit at its nodal point N.

A is soldered at N to a brass arm (D) projecting from the vertical wooden back. The H.T. for the valve may be supplied through a pair of telephones *via* the nodal point of the tuned circuit. Under these conditions, the valve oscillates most freely. If, however, the connection is made to a point on the ring somewhat removed from the nodal point, the tendency to oscillate is greatly reduced; this gives us a very simple and convenient means of reaction control. A radial arm (E) of springy brass is pivoted about the centre (M) of the circle, and makes rubbing contact with the edge of the ring A in the neighbourhood of N. It is through this contact that the H.T. is supplied *via* the telephones. If the path of contact is kept smooth and clean, the reaction control is smooth and silent, but it is important that the area of contact should be small as well as definite. Lubrication with vaseline or oil frequently improves a rubbing contact—a rather surprising fact.

One great advantage of this method of controlling reaction, apart from its simplicity, is that it has but little effect on the tuning—a very important point. The reaction arm and its centre support should not be massive, and the amount of metal in them should be as small as possible to be consistent with robustness, so that eddy-current losses are reduced to a minimum.

To return to the tuning arrangement, Fig. 1 will serve to make the idea clear. J is a straight piece of brass rod soldered in to plate B and having a good, fairly fine thread. It passes through a hole in plate C which allows ample clearance. A nut (U) engages with the thread of J, and may be rotated by means of the anti-capacity handle (H) of wood, ebonite or glass. An insulating washer (S) keeps U out of contact with plate C, thus avoiding a short circuit, while a metallic washer may be inserted between S and U to improve the mechanical action.

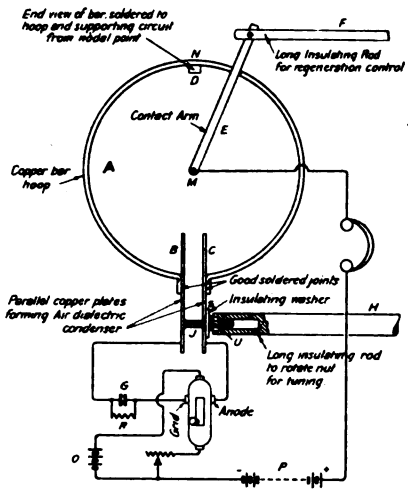

Fig. 1.

Great care must be taken with this part of the apparatus both mechanically and electrically. On the mechanical action much of the fineness of tuning depends. The washer S, as the one solid dielectric in the tuned circuit, requires particular attention. If ebonite is used, it should be of the very best quality and should be at least ⅛ inch. If a better substance than ebonite is available it should be used.

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Various arrangements no doubt occur to readers by which the dielectric flux through washer S could be reduced, but even in the case illustrated it would not appear to be very serious provided that a good dielectric is used. Of course, some support for the free end of H and the reaction rod (insulated at H) should be provided but it has not been considered necessary to encumber the diagrams with these details.

As far as the writer is aware, this would seem to be the nearest approach to a real low-loss tuner that has yet been devised.

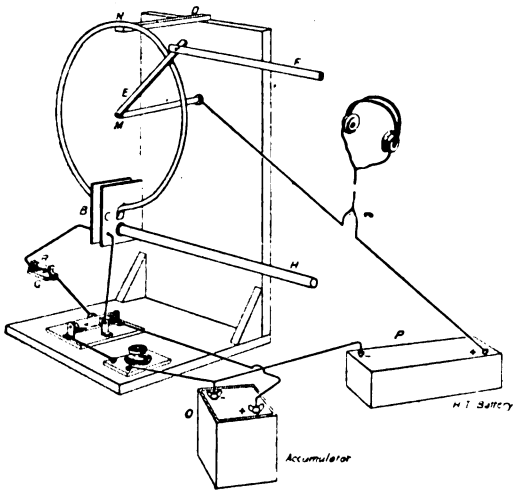

Fig. 2.

There is complete metallic continuity in the resonant circuit and solid dielectrics have been practically eliminated, in addition to which the ohmic resistance must be almost negligible. The remaining snags are the glass dielectric in the valve and the valve-holder, if one is used. If desired, the valve-holder may be abolished and direct soldered connections made. At the time of writing, however, the author has not tried this refinement, a V24 valve in an ordinary sort of holder having been used. Four-pin valves in the usual four-pin socket usually work, but not with such certainty, since the losses in the holder sometimes prevent the set from oscillating.

Exactly what is gained on these short wave-lengths by trying to cut down energy losses in tuners remains yet to be decided. There does not appear to be much margin on 3 metres between positive losses and the "negative resistance" due to regeneration, so that one must be careful if one wants a set to oscillate at all; but once a set is just on the point of oscillating, or just actually doing so, the open question remains: "Is it worth reducing the losses any further?" The writer of this article certainly does not know for certain yet. One point worth bearing in mind is that at the enormous frequencies under consideration the radiation resistance of the single turn may quite likely be greater than all the other losses of the circuit put together; and it is no good trying to reduce the radiation resistance of a receiver, because this would necessarily entail destroying its properties as a pick-up.

So far no dimensions have been given. It is no use designing a circuit of this type and then trying to calculate its wave-length by first calculating the inductance and capacity. The capacity between the plates may be worked out easily enough by measuring the dimensions of the plates and the distance between them; but it is not so with the inductance. In most good text-books you will find a formula for the inductance of a single turn of round wire, but this gives hopelessly wild results, because the formula assumes a current uniformly distributed through the cross-section of the wire.

Now, if you pass an H.F. current through a straight piece of wire, it confines itself almost entirely to the surface of the wire. If you bend the wire into a circle, things are worse still, as the current tends to confine itself to the innermost edge, so that a kind of new moon-shaped distribution of current results. Therefore, any simple theoretical formula is of no use in the case under discussion. The only thing, then, is to find one's own dimensions by experiment. The following dimensions gave a receiver which, according to some rough Lecher wire experiments, covered a range of about 3·5 to 5 metres:—

Inductance (A): Copper strip 8 in. mean diameter, $\frac{1}{4}$ in. wide by $\frac{1}{8}$ in. thick.

Condenser plates (B and C) each 4 in. by 3 in. by $\frac{1}{16}$ in. thick. Greater length horizontal.

Minimum distance between plates, $\frac{1}{8}$ in.

Maximum distance between plates 1 in.

There are few other miscellaneous details to mention. An ordinary kind of grid condenser is used, and the capacity should not be greater than .0001μF. The grid lead R may be taken across the grid condenser or to the positive filament terminal. If the

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leak is taken straight across the condenser, its resistance should be higher than usual—say, 5 megohms, as it has full H.T. across it. The arm D should give rigid support to the loop to avoid vibration; this is one of the reasons for using such thick material for the loop.

The disposition of the L.T. leads, the phone leads, as well as those of the L.T. battery (O), and the H.T. battery (P) is important. The two latter may be arranged compactly together behind the set out of the way of the H.F. circuit, while it is advisable to take the L.T. and phone leads straight back from the apparatus in a direction parallel to the axis of the loop A. This reduces coupling between these leads and the H.F. circuit. Loose contacts between conducting bodies anywhere in or near the receiver should be avoided, as their effects are exaggerated at these frequencies.

The question of coupling a 4-metre receiver to an aerial is not within the scope of this article. Suffice it to mention that "tight" coupling between the receiver and a straight wire is obtained when the wire is in the same plane as the receiver coil and within a foot of it. One readily gets stray coupling effects to wires, pipes, etc., that may be present near the scene of operations.

It is interesting to note that when one is listening on 3-5 metres, one gets a lot of QRM from the ignition of motor vehicles passing in the neighbourhood.

There appears to be no ostensible reason why the above method of constructing a receiver should not be adapted for wavelengths up to 20 metres or more, for there would be no great difficulty in replacing the one-turn coil by three or five convolutions, with the reaction arm acting over one of them.

Some Recent Books. [R020

We deal below with some new books of most varied intention, from the simple to the "high-brow."

"The Story of Broadcasting."

THIS, by the Director of Programmes to the B.B.C., *alias* "Uncle Arthur" (alas, too seldom heard nowadays), *alias* A. R. Burrows, F.J.I., is very much more than a story of the B.B.C. It begins, in fact, with a chapter which aims to give a non-technical idea of the essential similarity of all types of ether wave, while Chapter II. is devoted to the "Milestones" of wireless. Broadcasting in morse is covered, both as to S.O.S. calls and Press and propaganda, and some very interesting information is given as to German war wireless, with which Mr. Burrows was in official touch at this end.

The author reminds us that Fessenden succeeded in experimental telephony as far back as 1902, but goes on to explain how the coming of the valve made it practicable. The initial concerts from Chelmsford in 1920 introduce broadcasting in the modern sense of the word.

From this onwards, the history does become one of the B.B.C., and very interesting it is, for it is not only history, but a detailed description of the inside workings of this great organisation, with some most interesting details as to staff personalities, illustrated by an excellent series of portraits.

Published by Cassells, at 3s. 6d.

"Broadcast over Britain."

VERY different from the various other excellent books by B.B.C. personalities, this work reflects very strongly the personality of its author, Mr. J. C. W. Reith, the Managing Director of the Company.

In most cases these other books have been designed to give the curious a peep behind the scenes, as it were—and most admirably they have done it. Mr. Reith's book, on the other hand, is really a treatise on the ethics and policy of broadcasting, the B.B.C. being useful as an example.

To a certain extent the book is a statement of the aims and ideals of the B.B.C., with one or two delicate hints as to reasons why some of them have not yet been fulfilled.

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In our opinion, Mr. Reith is almost *too* delicate in dealing with some of the sources of opposition—he mentions none of them by name. As he says, the company has always left open a door for negotiation in these cases, so perhaps he "lets them down lightly" to prevent the closing of that door. But we fear that the success of the B.B.C.'s own symphony concerts and plays will prevent any reconciliation with the choleric gentlemen who are the head and fount of the concert and theatrical opposition.

As we have already mentioned, *Broadcast over Britain* reflects its author's strong and strange personality. It is serious, idealistic —even at times a little mystical. It is not nearly so "entertaining" as some of the other broadcasting books. But for those who have a real and deep interest in this wonderful thing we recommend it as food for thought.

It is published by Hodder & Stoughton, at 6s. net.

"Alternating Current Rectification."

BY L. B. W. Jolley, M.A., M.I.E.E., A.M.I.C.E., A.Amer.I.E.E., of the research staff of the G.E.C., this is essentially a handbook of power rectification.

For this reason, little of it applies directly to wireless work: for the conditions are very different. In power work, efficiency is of paramount importance, while in most wireless uses of rectifiers suitability, cheapness and other factors are often more necessary.

His general mathematical analysis is, of course, applicable to all rectification, but after this there follows Part II. on mechanical rectifiers of which little is useful for our particular purposes, except for battery charging.

Part III., again, on Gaseous Conduction, begins with five chapters on Mercury Arc Rectifiers, which, however great their importance for high power commercial rectification, are of little interest to the wireless reader. The one chapter on rectifying by thermionic valves of the usual type is excellent as far as it goes, and is followed by a chapter covering Neon tubes, the Tungar, etc. The new "S" tube is not mentioned, except in a short paragraph on p. 271 which may refer to it.

This is followed by a chapter on "freaks" and methods not yet developed.

In discussing the electrolytic rectifier we came upon one of the few hints of immediate use to the wireless man: the author gives some information as to the tantalum rectifier, and also mentions that tungsten in either nitric, hydrochloric, or sulphuric acid makes a good rectifier, with lead as the cathode. He quotes as a result from using the filament of a 60-watt lamp, the successful rectification of ·5 amp: strength of electrolyte 1 200 S.G. A 5 per cent. solution of potassium bichromate also gave good results.

Part V. is devoted to wireless rectifiers (*i.e.*, detectors). Here, unfortunately, the author is not thoroughly abreast of his subject. He has fallen into a familiar trap when dealing with valve grid current rectification, and when dealing with crystals shows one whose characteristic does not pass through the zero point, which is a novelty to us, though conceivably possible. This section might well have been omitted.

The book is well produced and indexed, and copious bibliographies are provided for each chapter. While, as we indicate, it contains little of immediate use to the wireless enthusiast, it is valuable for those (like ourselves) who consider the acquisition of knowledge of allied subjects to be one of the best guides to success in our own sphere.

xvii.+351 pp., copiously illustrated.

Published by Chapman & Hall, at 25s. net.

"Wireless Valve Transmitters."

THERE is no doubt that a book on this subject is called for, and the author, Mr. W. James, has undoubtedly devoted considerable time to its production. Nevertheless, we must confess that the result hardly satisfies us.

To begin with, the first three chapters, amounting to 58 pp., are devoted entirely to the study of the fundamentals of circuit law—Resistance, Inductance, Capacity, etc. This is excellent in itself. But surely the prospective reader—presumably the owner of a transmitting licence—must know it already! It seems out of place in a specialist work of this type.

There are other points where not quite sufficient care has been taken. For example, when considering 3- and 6-phase rectifiers for H.T. supply, the author states that each valve passes current for only $\frac{1}{3}$ or $\frac{1}{6}$ of a cycle, which does not seem correct, and the resulting wave form is quite incorrectly

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shown. Again, the typical loose-coupled transmitting circuit (sometimes called the "reversed feed-back") is classed as a variety of Hartley, whereas the loose coupling makes it essentially different; while in describing the Meissner circuit, no particular mention is made of its most serious disadvantage, that its wave-length depends entirely on the aerial, and is therefore often unsteady.

On p. 177, the Author is, quite rightly, calling attention to the importance of low loss in condensers; but he states that ordinary variable condensers have a "fairly high effective resistance," and recommends the use of mica condensers as having "fairly low losses." Both statements appear to us of doubtful truth.

The output from a set supplied by pure A.C. is described as "completely modulated." How then would the author describe what we usually call complete modulation; that in which the anode volts rise from say 0 to 2A (the A.C. supply, of course, varies between +A and —A)?

There are other little obscurities of a similar nature, which might give trouble to the comparative beginner.

viii.+271 pp., well illustrated.

Published by The Wireless Press, at 9s.

"Captain Eckersley Explains."

THE Chief Engineer's book is, primarily and beyond everything else, an explanation in reply to some of the criticisms addressed to the B.B.C. Those of us who have technical knowledge realise the wonderful work done by the Company's engineers; but the uninformed often do not realise in the slightest the difficulties of the task, and to them Capt. Eckersley addresses himself.

The author states at one point that the book is in no way to be taken as official, but of course this can hardly be taken literally, for (whatever his own wishes) it will be certainly taken as at any rate semi-official. Essentially, it shows how to avoid some of the most common troubles: it is divided into four chapters. Of these the first deals with the technical policy of the B.B.C.—such questions as 5XX, and so forth. Next, "Signal strength," deals with modulation on the transmitting side, and such matters as aerial design, fading, etc. We are at one with the Author on the all-important "factor of safety" in receiving.

On "Interference" also we are in general agreement with the author. But as regards the amateur's position we do not see eye to eye with him, as explained in the November issue of E. W. & W. E.

Lastly, he writes of "Quality," and gives some idea of the principles of the microphone and amplifier, with some interesting notes on echo.

86 pp., illustrated.

Published by The Wireless Press, at 2s. net.

"Uncle Jack Frost's Wireless Yarns."

AS a reprint of technical talks broadcast by Capt. C. C. J. Frost, M.I.R.E., of the Headquarters' engineering staff, we expect this book to be essentially simple; and since it is for those hitherto entirely unversed in wireless work, it must above all be accurate. Unfortunately it fails in the latter respect.

A statement on the subject of the Heaviside layer—that "iron" particles are the cause, may be simply a misprint for "ionic" (though it occurs twice). But what about the case of a man with a 300-yard aerial? He naturally got 2LO only faintly: but Capt. Frost says, "It was really astonishing that he received anything at all, *but he must have been receiving one of the harmonics*" (the italics are ours). What about a telephone diaphragm which will not vibrate more than approximately 1 000 to 1 500 times per second (p. 49)? And here have we been designing amplifiers to reach 10 000 cycles!

Again, on p. 86, the author has stated that by putting a second wire on an aerial both inductance and capacity are increased, an obvious fallacy. And there are others. We must say that we think it hard on the beginner to have his progress retarded by such misleading statements, even if they are due simply to haste.

106 pp. illustrated.

Published by The Wireless Press, at 2s. net.

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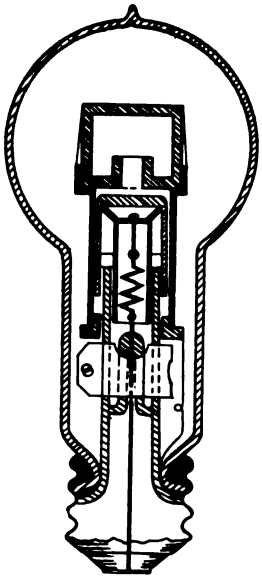
"S-Tube" Rectifiers.

WE have received for test two S-tube rectifiers as produced by the American Radio and Research Corporation (Amrad), and handled in this country by Messrs. Sanders Bros. & Co., Ltd., 54, Gresham Street, E.C.2. To those experimenters who study American journals these tubes will be familiar by name, but hitherto they have, unfortunately, not been obtainable in this country. The S-tube has the advantage of being very robust and having no filament to bother about, a gaseous ionic discharge being used instead of a pure electron discharge. There are two electrodes in the bulb, which contains helium gas under a reduced pressure of a millimetre or so of mercury. The rectifying action involves the "short path" principle, details of which are to be found in a recent issue of E.W. & W.E. The electrodes are made of carbon, the larger being the hollow carbon cylinder which is the chief visible feature within the bulb, and the smaller electrode being concealed from view by the carbon cylinder. As the business part of the discharge takes place within this carbon cylinder, there is practically nothing to be seen when the tube is in operation; sometimes in a darkened room a faint yellow glow may be observed. Presumably the reason why helium has been chosen as the discharge medium is that it has a low ionising potential (200 volts or less, according to conditions), and also that the mean free path of the helium molecule at low pressures is about twice as long as with any other gas.



The S-Tube in section.

The particular S-tubes submitted to us for test are rated to pass a maximum current of 100 milliampères at 1 000 volts. We have had these tubes installed under working conditions at our experimental transmitting station for several weeks. During this period they have been in constant use for rectifying about 1 000 volts A.C. at 50 cycles and have proved most satisfactory. Their efficiency is greater than that of the electrolytic rectifier and compares very favourably with that of the thermionic valve rectifier. There appears to be a minimum voltage of about 200 below which no conduction takes place, but once this voltage is exceeded by 100 volts or so the effective impedance seems to drop to a very low value. Certainly on voltages above 500 the tubes will pass almost any current that a normal transmitting valve is likely to take. The advantage of being able to fit up any full-cycle rectifying circuit without having to bother about separately insulated filament supplies can only be fully appreciated by those who have had to work with the ordinary thermionic rectifier. A couple of S-tubes work extraordinarily well with the condenser doubling circuit shown for electrolytic rectifiers in EXPERIMENTAL WIRELESS, Vol. I., No. 3, p. 158. The tubes may be worked with perfect safety at the makers' maximum rating; they warm up after running for some time, but never become violently hot, indicating that there is not an unreasonably large amount of power wasted in the rectifiers themselves. They are intended to run warm normally. The tubes we have tested will rectify quite well above the rated maximum of 1 000 volts, but we can say nothing at present as to the advisability of over-running them. A test with one of the tubes on a separate D.C. supply showed that when 1 500 volts potential was applied to the tube in the inverse direction only 4 or 5 milliampères were passed, while the tube acted almost as a dead short-circuit to the source when this was connected in the conducting direction. The rating of a hundred watts per S-tube is a liberal allowance for most amateur work, and the tubes function quite well on much lower powers. Where greater power is required a number of tubes may be run in series or parallel as in the case of electrolytic rectifiers

It is important, the manufacturers tell us, not to switch a cold S-tube on to full power at once. Where a potential of above 750 volts D.C. is to be delivered it is necessary, in order to bring the tube up to the required condition, to insert a resistance of 8 to 10 ohms in the primary circuit of the transformer when starting and to keep this resistance in circuit for one minute. After one minute this resistance may be short-circuited and the tube is ready to deliver its rated voltage. Since the tube cools slowly, after once it has been heated, it is not necessary to use the resistance to restart within a period of one hour. When starting at greater intervals the resistance should be used. The reason for this precaution is that the insulation resistance of the tube depends upon the purity of the helium gas which the tube contains. The tube, when in operation, has the characteristic of cleaning up the impurities of the gas. On cooling these impurities are released, making it necessary to reduce the voltage when starting.

As regards the life of an S-tube, we have no definite data, but (apart from mechanical breakage) this would appear to be indefinitely long. The makers give 3000 hours as a conservative estimate.

It is well to note that S-tubes are made to fit screw holders such as are standard in America for electric light fittings.

This form of rectifier is probably the nearest approach to the ideal for the experimenter that has been yet commercially realised.

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Long-Distance Work.

By Hugh N. Ryan (5BV) **[R009·2**

In view of the extraordinary advance in this section of the science that has taken place since last winter, we feel that the re-introduction of this series will be appreciated.

NOW that the season of long distance work is with us again, I am resuming the monthly reports on this branch of our work, which were published last winter under the title of "The Month's DX."

I might start right away by writing an account of all that has happened since the last report appeared, but I think our readers will get the facts in better perspective if I write them in the three divisions into which they naturally fall: *i.e.*, work done during the summer; work done at the beginning of the "DX" season (September and early October); and work done in October and November—the last-named forming the first of the ordinary monthly reports.

The article will, then, be rather in diary form, each of the three parts having been actually written at a time current with the events chronicled.

Work done during the Summer, 1924.

In order to bring last season's readers up-to-date I will commence by reviewing the work which has been done during the summer. This has been quite considerable, and we might have cause to congratulate ourselves on a very good summer performance, but for the deplorable fact that we lost touch with America and Canada for several months, and this in spite of the "summer" weather which, from a wireless point of view, if from no other, has been unusually favourable. This failure to maintain touch across the Atlantic is a sad end to our boast of last winter that we would "work 'em right through the summer." However, next summer I think we really will do it, provided that the Americans don't go to sleep and forget to listen for us, as I suspect that most of them did this time.

Some interesting data on the way in which signal strength varies over the "Pond" is provided by a well-known Canadian amateur who spent a considerable part of the summer in a ship anchored in mid-Atlantic. He tells me that right through the summer my own signals were very strong out there, and so were those of Canadian 1AR.

It is curious, therefore, that 1AR and I were quite unable to hear each other, in spite of repeated attempts. Other signals reported to be strong in mid-Atlantic were those of 2KF, 5LF, 5KO, 5MO, 5MA, 2NM, to mention a few of the strongest among a large number, which also includes several well-known Continental stations, such as Danish 7EC, and Belgian W2.

The station which was reported as one of the most consistently strong was 5KO, which reminds me that we have now lost that famous Bristol station, its owner having left Bristol. He is now in Newcastle and may sometimes be heard from 5MO and 2CC.

At the time of writing the last notes, we were just beginning to hear amateur signals from Finland, and naturally concluded that another country was just "starting up." It was, therefore, with considerable surprise that we learnt there were some 150 Finnish stations in operation, and that they have had a fully organised Relay League for some years! The only question which arises is why we never heard them before. Even now we don't hear many of them. They are numbered by districts, in the same way as the Americans, and every call-sign begins with the number of the district and the letter N. The strongest signals seem to come from 1NA, 2NM and 3NB and several British stations have worked with these.

A considerable number of Swedish stations have appeared during the summer, their calls all beginning with "SMZ." The best known in England are SMZP, SMZS, SMZV and SMZY, all of whom produce quite strong signals.

The Italian amateur, Adriano Ducati, whose call sign ACD was very familiar to most of us last winter, has been carrying out some experimental work for the Italian Navy, on board a ship with the call sign IHT. The most distant point which he visited was the

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Brazilian coast, and even from there his signals were very strong in England. While he was there he received strong signals from British 2KF, which is a very fine achievement. 2KF thus holds the enviable record of being the first British amateur heard in South America. Speaking of records, our last year's readers may remember two unconfirmed records which I mentioned—the reception of 2JF by American 8CWR on October 12, 1923, and my own working with American 8AJW on December 2. These have now both been confirmed, thus establishing 2JF as the first British amateur to be heard in U.S.A. and 5BV as the first British amateur to effect two-way communication with U.S.A. and the only European amateur to do so on 200 metres. The communication between 5BV and 8AJW was very short and spasmodic, and it is claimed merely as a record, since as an actual performance it does not, of course, compare with the reliable communication achieved by 2KF, a few days later, on a shorter wavelength.

"The beginning of the 1924-25 DX Season."

We now come to the time when working with Americans and Canadians is just starting again. The whole position has been altered recently by the revision of the conditions under which the Americans are licensed. Last year the ordinary American amateur was licensed for 150-200 metres only, and special experimental stations for 110 to 150. This has now been changed, and only a very few are still allowed on 100-150 metres, while all of them are now allowed to work on 4 to 5 metres, 20 to 22 metres, 40 to 45 metres and 75 to 80 metres. Interest on this side centres at present on the 75-80 metres band, on which large numbers of Americans can be heard every night, often faster than they can be written down. There is no doubt that this band is a real "discovery," and the Americans are making the best of it. The only trouble is that, since we are not allowed the same band, all Transatlantic work this winter will have to be on two wave-lengths, our stations being on about 115 metres* and the Americans on 75-80, while the Canadians appear to be everywhere between 50 and 200 metres. This two wave-length working will be a great advantage once it gets going, as stations on both sides will be free from local QRM, which was so troublesome last year, but at present the difficulty is that nearly all the American stations transmitting on 75-80 metres listen only on this wave. A few of them are slowly realising that they must listen higher up, and as a result of this several of our stations, notably 2OD, 2KF and 5LF have already worked them, but it is still very difficult to "hook up." It will be very useful if every British amateur who sends cards to the Yanks puts a note on each card, reminding the American to listen on about 115 metres* when he sends a CQ call on 75-80. Several London stations are doing this and it is slowly bearing fruit.

An attempt is being made to run a relay through from England to Australia via America. It should be easy enough if it were properly organised, as all the links are working, but it is quite an impromptu affair. It may succeed, with any luck, and we hope it will. The chief obstacle to any impromptu relay is that, in spite of their boasted relaying efficiency, American stations nearly always seem to forget to QSR messages sent to them from this side.

October-November.

We have to record at this time what is probably the most important event in the history of amateur radio, and certainly the most important in British amateur history. We have at last "got through" to the Antipodes.

It is curious that, though we had for a long time had visions of working "right across the world," and some of us (including myself) had prophesied that it would come off this winter, we had, somehow, always thought of Australia as our goal. We had never given a very serious thought to the more exact Antipodes, New Zealand, and no attempt, as far as I know, had been made to work with that country, though several attempts were made at either direct or relay communication with Australia. The reason, I suppose, was that Australia, as the bigger country, seemed a more natural goal (or a bigger target, perhaps!) though most of us had heard of "the world's best receiving station"—New Zealand 4AA.

*Since writing the above, a number of the best-known British amateurs have adopted 90-100 metres as their transmitting wave, though 115 is still in use also.

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When the great result was achieved, it happened in a very casual sort of way, without any preliminary attempts. On the morning of October 18th G2SZ wanted to connect with a first district American station, and could not succeed in "raising" him. He asked G2OD to try to attract the American's attention, and 2OD did so, only to find, when he came back to call 2SZ, that the latter was working Z4AA, who had called him in the interval! 2SZ had heard the New Zealander's first call to this country, and Z4AA had heard 2SZ's first reply.

2SZ tells me that his feelings on first "hooking" a New Zealander were exactly the same as my own, a year ago, when I first worked a Canadian: he just couldn't believe it! However, the cable service was, as usual, called upon to convince him, and he received a confirmatory cable message next day.

This achievement was indeed an occasion for rejoicing in amateur circles, but for its immediate sequel I shall never forgive myself. I first heard the news by radiophone from 2KF the following night. We both decided to stay on all night and see what we could do, but soon after 5 a.m. I got "fed up"—having heard nothing all night but a few Yanks—and, deciding that 2SZ's effort was only an unrepeatable freak, went to bed.

A few minutes later 2KF heard Z4AA—and worked him! Such is life. Since then the following stations have succeeded in communicating with New Zealand: British 2OD, 2NM, 2WJ, 5NN, 2JF, 5LF, 6TM and French 8BF. British 2SH and 5BV have been heard in New Zealand, but have not, so far, worked both ways, neither of them having had time to come "on the air" often.

The New Zealand "Big Three" are: 4AA, 4AG, and 4AK, though 2AC has been heard several times. It is a curious fact that all these three stations (4AA, 4AG, 4AK) are within a few miles of each other, and of our direct Antipodes (which is in the sea off the East Coast of the South Island). They are, we understand, all quite low power stations compared with some of the North Islanders, of whom 2AC is the chief; and yet 2AC is seldom heard and the other North Islanders never.

It is to be presumed that our waves, going out in all directions, come to a focus somewhere at or near the Antipodes, making low power communication with that point much easier.

For the benefit of those who have not yet heard them, I may say that 4AA uses pure C.W., 4AG uses C.W. with a fairly distinct A.C. "mush" in it, and 4AK practically raw A.C.

So far we have only worked them in the mornings (their evenings), but we should be able to do it "when it's night time in New Zealand" just as well as "when it's night time over here." For this purpose everyone is specially requested to listen for them (on about 80 metres) between 6 p.m. and 7 p.m. Greenwich Mean Time, when they are transmitting for us.

Several Australian stations have been reported over here, and several of our men have been reported in Australia.*

Working with Americans and Canadians is still not very easy, though a certain amount of work in this direction is done on most nights.

Several of the Americans have worked New Zealand, and at the moment of writing I have just heard Canadian 1AR ("Globe-trotter Joe") calling New Zealand 4AG, whom he is receiving well.

That is, I think, all the news; but before concluding may I remind you that if this monthly article is to be as interesting as it should be, I must have reports of their activities every month from every station engaged in DX work? Please let me have them by the 10th of each month at the latest, and *don't forget.*

---

* THE LATEST "DX" RECORD.

It is with pleasure that we are able to announce that successful two-way communication has been effected for the first time between the British Isles and Australia.

The station at this end was worked by Mr. E. J. Simmonds (200), of Meadowlea, Gerrard's Cross, Bucks., who exchanged signals with Mr. M. Howden (3BQ), of Boxhill, Melbourne, Victoria, on Thursday, the 13th of November. Mr. Simmonds worked on a wave-length of 95 metres with an input of 105 watts.

3BQ worked on 75 metres, and, apart from that, no particulars of his power, etc., are available at present.

Continuous exchange of messages was kept up from 6.50 a.m. to 7.15 a.m. Prior to 7.15, the Australian signals were perfectly clear, but afterwards faded quickly and soon became inaudible.

It would seem that we have reached the goal in DX work, and look forward to the time when these long distances will be bridged by the phone.

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A Short Radio Course of Esperanto, the International Language. [R800

PERHAPS a few introductory remarks on the subject of an international language for radio will be of interest to our readers.

To the vast majority of the world's inhabitants who have never travelled abroad or corresponded with other countries or rubbed shoulders with foreigners, the need of such a language has not seemed vital until the advent of radio telephony. Now it is possible, while seated in one's most comfortable armchair at home, to hear voices from many lands and in many tongues. A novelty on the first occasion, to be sure, although incomprehensible and meaningless, but afterwards a mere waste of good "juice"!

As with the "broadcaster" so with the experimenter. The dots and dashes, as well as telephony, are easily picked up from abroad, but unless *all* foreign transmitters in whatever countries they dwell can work in English, or, conversely, unless the British amateur is conversant with all the languages spoken or "tapped" out, little really effective work can be done.

Esperanto comes as a "boon and a blessing" to such — it needs only co-operation in each country, and very soon an experimenter here will be able to carry out tests with his foreign friends to an extent never before hoped for or even thought possible.

Although this Course contains the whole of the grammar of Esperanto it has of necessity been written in a most compact form.

Experimenters desirous of making a really serious study of the language should obtain one of the many excellent textbooks published, and should, if possible, join a local Esperanto society or class. There is nothing like personal tuition—particularly for *conversational* practice—and the reader who wishes to use the language in front of a microphone or joined to a pair of earphones should obtain as much speaking and listening practice as possible. Failing that, enrolment in a Correspondence Course or even the study of a textbook will suffice to enable a keen student to obtain a good grip of the language very quickly.

The feature that immediately strikes the learner is the use of accented letters. Those who are accustomed to send and receive Morse will wonder how these can be telegraphed without the invention of special Morse signs. All that is necessary is to replace the circumflex accent by the letter "h," thus: write "ch" for ĉ, "sh" for ŝ, etc.

Esperanto can therefore be telegraphed just as easily as any national language without accents.

In order to assist students of this fascinating language, arrangements have been made to correct and criticise any exercises sent in; each piece of work to be accompanied by 3d. in stamps to cover postage to our contributor and return. Please address such communications to: ESPERADIO, c/o EXPERIMENTAL WIRELESS AND WIRELESS ENGINEER, 19, Surrey Street, Strand, W.C.2.

THE GRAMMAR OF ESPERANTO.

THE ALPHABET.

A a B b C c Ĉ ĉ D d E e F f G g Ĝ ĝ
H h Ĥ ĥ I i J j Ĵ ĵ K k L l M m N n
O o P p R r S s Ŝ ŝ T t U u Ŭ ŭ V v Z ẑ

Note.—No Q, W, X, or Y.

PRONUNCIATION.

The VOWELS sound as in Italian :—

A	E	I	O	U
par	*pear*	*pier*	*pore*	*poor*
are	*there*	*three*	*or*	*two*

Most CONSONANTS sound as in English, **C** is like **ts** in beat ; thus, **caro** like *tsaro* ; **acido** like

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ah-tsee-doh. **Ĉ** like **ch** on **church.** **G** like **g** in **galena.** **Ĝ** like **g** in **gem.** **J** like **y** in **yes,** e.g. **jaro** like *yaro,* **bojo** like *boyo.* **Ĵ** like **z** in **azure.** **S** like **s** in **so.** **Ŝ** like **sh** in **show.** **Ĥ** (used in very few words) like **ch** in **loch** (guttural).

DIPHTHONGS (Vowel Glides):

AJ, OJ, as in **my boy. EJ,** as in **obey. UJ** as in **hallelujah** or in **ruin.** **Ŭ** is the Esperanto **W; AŬ** as **ow** in **how.**

The ACCENT is always on the last syllable but one. Phonetic spelling. No silent letters.

The **GRAMMAR** is based upon **SIXTEEN FUNDAMENTAL RULES.**

I.—THE ARTICLE.

A or **An** (the indefinite article) is not expressed. *Anteno,* an aerial.

The (definite article) in Esperanto is **La,** which never changes. *La krado,* the grid. *La kradoj,* the grids.

II.—THE NOUN.

All Nouns (names of things, places or persons) end in **O.** *Borno,* a terminal; *stacio* (pronounced stahtseeo) a station; *Londono,* London; *Johano,* John. To form the plural add **J** (pronounced as **Y**). *Fadenoj kaj telefonoj,* Wires and telephones.

There are only two cases: **Nominative** and **Accusative** (objective)—the latter is formed from the Nominative by adding **N.** *Johano konstruas aparaton.* John is building a set. *La patro sendas mesaĝojn.* The father sends messages.

The question may be asked, Why the accusative ending in Esperanto? It is international and occurs even in English although irregularly, e.g., *me, thee, him, us, them, whom.* It removes ambiguities and makes the language flexible. Its abolition would introduce difficulties, especially to those nations whose word order is different from that of English.

Tomaso frapis Roberton.	Thomas hit Robert.
Roberton frapis Tomaso.	Ditto ditto (Note that the **n** distinguishes the object wherever the word is.)
Roberto frapis Tomason.	Robert hit Thomas.
Tomason frapis Roberto.	Ditto ditto (As above.)

The DAYS of the WEEK are:

Sunday, *dimanĉo.*	Thursday, *ĵaŭdo.*
Monday, *lundo.*	Friday, *vendredo.*
Tuesday, *mardo.*	Saturday, *sabato.*
Wednesday, *merkredo.*	

The MONTHS of the YEAR are:

January, *Januaro.*	July, *Julio.*
February, *Februaro.*	August, *Aŭgusto.*
March, *Marto.*	September, *Septembro.*
April, *Aprilo.*	October, *Oktobro.*
May, *Majo.*	November, *Novembro.*
June, *Junio.*	December, *Decembro.*

Christmas Day, *Kristnaska Tago*; Easter, *Pasko*; Whitsun, *Pentekosto.*

III.—THE ADJECTIVE.

All Adjectives (words which qualify or describe nouns) end in **A.** They agree with their noun in number or case. *La lerta amatoro desegnis novan cirkuiton.* The clever amateur designed a new circuit. *Grandaj stacioj sendas longajn ondojn.*

The **Comparative** is formed by using **Pli-ol** = more-than. *Dika fadeno estas pli utila ol maldika.* Thick wire is more useful than thin wire.

The **Superlative** is formed by using **Plej (-el)** = most (-of). *Galeno estas la plej populara el (la) kristaloj.* Galena is the most popular of (the) crystals. *Donu al mi la plej grandan transformatoron.* Give (to) me the largest transformer.

IV.—THE NUMERALS.

The **Cardinal Numbers** are:

1 **unu**	5 **kvin**	9 **naŭ**	13 **dek tri**
2 **du**	6 **ses**	10 **dek**	20 **dudek**
3 **tri**	7 **sep**	11 **dek unu**	25 **dudek kvin**
4 **kvar**	8 **ok**	12 **dek du**	50 **kvindek**

100 **cent,** 138 **cent tridek ok,** 1,000 **mil,** 1,924 **mil naŭcent dudek kvar.** 1,000,000 **miliono.**

Nouns are formed from them by adding **-o:** *unuo,* a unit; *milo,* a thousand; *dek-duo,* a dozen.

The **Ordinal Numbers** (adjectives) are formed by adding **-a** (the adjectival ending) to the foregoing numbers; *unua,* first; *dua,* second; *tria,* third; *kvardek-kvara,* forty-fourth; etc.

The **Ordinal Adverbs** are formed by adding **-e** (the adverb termination) to the cardinal numbers. *Unue,* firstly; *due,* secondly; *trie,* thirdly; *sepdek-oke,* seventy-eighthly; etc.

For **Multiples** (in English -fold, as in hundredfold), add **-oblo, -obla** or **-oble** respectively for a noun, adjective or adverb.

duobla, double. *triobla,* treble, threefold.
duoble, doubly. *trioble,* trebly.
duobla fadeno, a double (twofold) wire, thread.

For **Fractions** add **-ono, -ona,** or **-one;** *duono,* a half; *duona,* half (adjective); *duone,* by halves.

For **Distributives** use the prefix **po,** at the rate of: *po kvar pencoj por ĉiu,* at fourpence (for) each.

For **Collectives** add **-op:** *duope,* by twos; *unuope,* one at a time, singly; *dekope,* by tens, in tens.

V.—THE PRONOUN.

The **Personal Pronouns** are:—

mi, I	**ni,** we
ci, thou	**vi,** you
vi, you	**ili,** they
li, he	**oni,** one
ŝi, she	**si,** himself, herself, etc.
ĝi, it	(Used only in reflexive.)

The **Possessive Pronouns,** being adjectives, are formed by adding **-a:**

mia, my, mine	**nia,** our, ours
cia, thy, thine	**via,** your, yours
via, your, yours	**ilia,** their, theirs
lia, his	**sia,** his own, her own, their own, etc. (reflexive only).
ŝia, her, hers	
ĝia, its	

The above words being in effect adjectives, take the endings **-j** and **-n** when necessary.

Li invitas siajn amikojn, He invites his (own) friends.

Mi rompis mian valvon, I broke my valve.

Liaj amikoj estas miaj, His friends are mine.

Oni aplaŭdis vian kanton, Your song was applauded (one applauded your song).

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VI.—THE VERB.

The **Verb** (denoting action or state) does not change for person or number.

For the **Present** time (or tense) add to the verbal root **-AS.**

For the **Past** time (or tense) add to the verbal root **-IS.**

For the **Future** time (or tense) add to the verbal root **-OS.**

mi estas, I am — *mi estis*, I was
li iras, he goes — *li iris*, he went
vi laboras, you work — *vi laboris*, you worked
mi estos, I shall be
li iros, he will go
vi laboros, you will work

The **Conditional** mood takes the ending **-US.**

Se vi lernus, mi ankaŭ lernus, If you were to learn, I would also learn.

The **Imperative** (command) mood takes the ending **-U.** *Lernu Esperanton*, Learn Esperanto.

The **Infinitive** (indefinite) mood, takes the ending **-I.** *Paroli*, to speak. *Promeni*, to walk. *Viziti*, to visit.

Every verbal ending is applicable to every verb in the language, without exception.

The **Active Participles** (with adjectival, substantival, or adverbial sense respectively) :—

Present end in **-ANTA, -ANTO, -ANTE.**
Past end in **-INTA, -INTO, -INTE.**
Future end in **-ONTA, -ONTO, -ONTE.**

La frato estas studanta Morson, The brother is studying Morse. *Studanta viro*, A studying man. *Studanto*, a student. *Studante, oni lernas*, By studying one learns. *La policano estas parolinta*, The policeman has spoken. *Parolinto*, a speaker (after he has spoken). *Parolinte, li sidiĝis*, Having spoken, he sat down.

La sendilo estas funkcionta, The transmitter is about to work (function).

La kantonto, The singer (the person about to sing).

The **Passive Participles** (with an adjectival, substantival, or adverbial sense) :—

Present end in **-ATA, -ATO, -ATE.**
Past end in **-ITA, -ITO, -ITE.**
Future end in **-OTA, -OTO, -OTE.**

La kondensatoro estas konstruata, The condenser is being constructed. *La batato*, The person being beaten. *Batate, li elkriis*, Being beaten, he cried out. *Amplifite, la signaloj estis tre fortaj*, Having been amplified, the signals were very strong. *Kuplitaj bobenoj*, Coupled coils.

All the forms of the **Passive Voice** are made by the aid of the verb **Esti,** to be (which is the only auxiliary verb in Esperanto), and a **passive participle** of the required verb.

La ricevilo estas agordata, agordita, agordota, The receiver is being tuned, has been tuned, is about to be tuned.

The preposition with the Passive is **de**—by.

La filamento estas varmigata de la akumulatoro, The filament is (being) heated by the accumulator. *Reakcio estos provizata de bobeno kuplita al la antena induktanco*, Reaction will be provided by a coil coupled to the aerial inductance.

The Esperanto verb is entirely regular. There are no irregular verbs to learn in Esperanto.

VII.—THE ADVERB.

Adverbs (words which modify verbs or adjectives) end in **E.**

Ne kantu rapide, Do not sing quickly.

The **Degrees of Comparison** are the same as with the adjectives, i.e., **pli** and **plej.**

Mia perikono detektas pli bone, ol via, My perikon detects better than yours. *Kiu funkcias la plej efike, diodo, triodo, aŭ tetraodo?* Which works most efficiently, a two-, three-, or four-electrode valve?

VIII.—THE PREPOSITION.

(A) All **Prepositions** require the **Nominative** Case after them.

Mi donis ĝin al **li** (*not lin*), I gave it to him. *Li aĉetis la eboniton por* **mi** (*not min*). He bought the ebonite for me.

The chief prepositions with their meanings are :—

al, to	**gis,** until	**pro,** on behalf of
ĉe, at	**kun,** with	**pri,** concerning
de, of, from	**por,** for	**tra,** through
el, out of	**per,** by means of	**trans,** across

(B) Each Esperanto preposition has a definite and constant meaning. If the meaning of an English preposition is not clear, it may be translated either by the preposition **je,** which has no definite meaning in itself, or by **-N** without a preposition provided that the meaning is clear.

Ili ridis **je** *li*, or *Ili ridis li***n,** They laughed at him.

Oni obeis **al** *li*, or *Oni obeis li***n,** One obeyed him.

IX.—PRONUNCIATION.

Every word is read as it is written, and there are no silent letters, e.g., *Kune* is pronounced *kooneh*, not *kewn*.

X.—ACCENT.

The **accent** or stress falls **always** on the **last syllable but one.**

*Fa**zo**, Rela**jo**, Reo**sta**to, Izola**to**ro, Alt**fre**kven**ca**, Potencio**me**tro.*

XI.—COMPOUND WORDS.

Compound words are formed by joining the various root-words together, the qualifying word coming first and the chief word coming last :—

Fulmŝirmilo, lightning arrester; *varmfadena ampermetro*, hot-wire ammeter; *laŭtparolilo*, loud-speaker.

Word-building on these lines is very frequent in Esperanto, and does away with the necessity of learning a vast number of words.

Agordi, to tune; *agordilo*, a tuner (an instrument for tuning); *oscili*, to oscillate; *oscilema*, inclined to oscilate; *ekoscili*, to break into oscillation; *teni*, to hold; *valvtenilo*, a valve-holder; *akumulatoro*, an accumulator; *akumulatorujo*, an accumulator case.

XII.—ORDER OF WORDS.

The order in which words are put in Esperanto is generally the same as in English, with the two following important deviations :—

(A) In **Interrogative Clauses** (asking questions), the order of the words is not inverted, as in English, but the word **ĉu** is used at the beginning of the

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sentence. It may be considered as a *warning* word to indicate that a question is coming. **Ĉu** is not required when an interrogative pronoun (*kiu, kia, etc.*) is used.

Mi parolas, I speak, I do speak. *Ĉu mi parolas ?* Do I speak ? Am I speaking ? *Mi parolis*, I spoke, I did speak. *Ĉu mi parolis*, Did I speak ? *Kiu blokas nun ?* Who is jamming now ?

(B) In **Negative Clauses** (denials), the word **ne** (not) is placed before the word it modifies. *Mi ne sendis lin*, I did not send him. *Ne mi sendis lin*, It was not I who sent him. *Mi sendis ne lin, sed ŝin*, I sent not him but her. *Malgraŭ la simpla cirkuito, ĝi ne estas ne-radianta aparato*, In spite of the simple circuit, it is not a non-radiating set.

XIII.—THE ACCUSATIVE OF DIRECTION AND MEASURE.

The **-n** of the Accusative Case is also used :—

(A) To show **direction towards.**

After **al** or **ĝis** the **-n** is unnecessary, as these words in themselves indicate direction.

Li iras Londonon, or *Li iras al Londono*, He goes to London. *La birdoj flugas en la ĝardenon*, The birds fly into the garden. *La birdoj flugas en la ĝardeno*, The birds fly (about) in the garden.

(B) To show **duration of time.** *Ili interkomunikis tri horojn*, They communicated with each other for three hours.

(C) To show **weight, measure,** or **distance.** *Li iris du mejlojn*, He went two miles. *La pano pezas du funtojn*, The bread weighs two pounds.

XIV.—PREPOSITION (see Rule VIII. B).

XV.—THE FOREIGN WORDS.

A large number of words, mostly of Latin or Greek origin, exist, which are common to most languages. These words, after being made to conform to the rules of phonetic spelling, may be used in Esperanto. They take the usual terminations. *Telefono, Telegrafo, Aeroplano, Markonigramo, Galvanometro, Volto, Farado, Omo, Teatro, Naturo*, etc.

All international scientific and technical terms are similarly adopted. Some radio terms have alternative Esperanto equivalents, such as *transformatoro* or *transformilo*, for transformer ; *kondensatoro* or *kondensilo*, for condenser ; *detektoro* or *detektilo*, for detector ; *koheroro* or *koherilo*, for coherer. In each case it may be taken that the latter form expresses the **general** meaning of the term, while the former has the special **technical** meaning ; e.g., *kondensilo* is derived from **-ilo,** an instrument, and *kondens-*, to condense, and means "an instrument for condensing," electrical or otherwise ; whereas *kondensatoro* is specially applied to electrical condenser.

XVI.—ELISION IN POETRY.

For euphony in poetry the final **O** of the noun (in the nominative case only) may be dropped and replaced by an apostrophe.

Al la mond' eterne militanta, To the world eternally fighting.

The **A** in **la** may be dropped when it follows a preposition ending in a vowel.

De l'soldato, of the soldier. *De l'maristo*, of the sailor.

WORD BUILDING IN ESPERANTO.

From all Esperanto roots, there may be formed by the application of certain fixed rules, a number of derived words, to express all shades of thought. Thanks to this, the amount of material required for a vocabulary of all words likely to occur in everyday life, is enormously reduced.

THE REMARKABLE FLEXIBILITY OF ESPERANTO.

Suppose you learn 500 root-words in Latin, French, Spanish, German or Russian.

You cannot with certainty apply any principle of word building.

So that, if you learn 500 words you have but them, and for the derivations you must learn about 2,000 NEW root-words.

BUT

Suppose you learn 500 root-words in ESPERANTO. Then :—

(1) By applying the grammatical endings **-O, -A, -E, -I,** you have **2,000** words at your command.

(2) Applying an average of 10 of the 30 prefixes to each of the 2,000 you now have **20,000** words at your command.

(3) Adding words formed with two or more words, made by adding one root to another root, we easily bring the number of words at your command up to **25,000.**

Thus, LEARN 500 WORDS AND YOU HAVE 25,000 !

HOW WORDS ARE BUILT UP.

To create new words, as mentioned above, we make use of :—

1. **Grammatical terminations** : for example, from the root *parol'* (which expresses the idea of speaking), we can form :—

parol'i, to speak ; *parol'o*, speech ; *parol'a*, oral, spoken ; *parol'anto*, speaker ; *mi parol'as*, I speak, etc.

2. **Compound words,** for example :—

en'ir'i to enter (*en* in, *ir'i* to go) ; *el'ir'i*, to go out (*el* out, from, *ir'i* to go) ; *rul'kurteno*, window-blind (*rul* to roll, *kurteno* curtain).

3. **Prefixes and Suffixes,** of which some thirty are in common use :—

-aĉ—denotes contempt : *domo*, a house ; *domaĉo*, a hovel ; *hundo*, a dog ; *hundaĉo*, a cur.

-ad—denotes action, or (where the root already signifies action) continued action (like English -ation, -ing) : *radio*, radio ; *radiado*, radiation ; *diri*, to say ; *diradi*, to keep on saying.

-aĵ—denotes something made from, or having the quality of what is mentioned : *malnova*, old ; *malnovaĵo*, an antique ; *metalo*, metal ; *metalaĵo*, a metallic article.

-an—denotes an inhabitant, member, adherent (like English -an, -man) : *kolegio*, college ; *kolegiano*, collegian ; *asocio*, association ; *asociano*, member of association ; *Londono*, London ; *Londonano*, Londoner ; *Kristo*, Christ ; *Kristano*, Christian.

-ar—denotes a collection of what is mentioned : *fadeno*, wire ; *fadenaro*, collection of wires, wiring ; *vorto*, a word ; *vortaro*, dictionary ; *libro*, a book ; *libraro*, a library.

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bo-—denotes a relation by marriage: *filino*, daughter; *bofilino*, daughter-in-law.

cj—these letters added to the first few letters of a masculine name make of it an affectionate diminutive: *Vilhelmo*, William; *Vilĉjo*, *Viĉjo*, Willie, Will, Bill; for feminine names add **nj** instead of **cj**: *Mario*, Mary; *Manjo*, Molly.

dis-—denotes separation (as in English): *tordi*, to twist; *distordi*, to distort; *doni*, to give; *disdoni*, to distribute.

-ebl—denotes possibility (English -able, -ible): *fleksi*, to bend; *fleksebla*, flexible; *porti*, to carry; *portebla*, portable.

-ec—denotes a quality (English -ness): *bela*, beautiful; *beleco*, beauty; *bona*, good; *boneco*, goodness.

-edz—denotes a married person: *doktoro*, doctor; *doktoredzino*, doctor's wife; *lavistino*, washer-woman; *lavistinedzo*, washerwoman's husband.

-eg—denotes enlargement or intensity of degree: *anteno*, aerial; *antenego*, an enormous aerial; *pluvo*, rain; *pluvego*, downpour, deluge; *granda*, great, large; *grandega*, immense.

-ej—denotes the place where an action occurs: *kuiri*, to cook; *kuirejo*, kitchen; *fabriki*, to manufacture; *fabrikejo*, factory; *generi*, to generate; *generejo*, generating station.

ek-—denotes the beginning or short duration of an action; *brili*, to shine; *ekbrili*, to flash; *ridi*, to laugh; *ekridi*, to burst out laughing.

-em—denotes propensity or disposition: *kredi*, to believe; *kredema*, credulous.

-er—denotes a unit, particle, atom, speck, etc., one of the parts which form a whole; *sablo*, sand; *sablero*, a grain of sand; *mono*, money: *monero*, a coin.

-estr—denotes a chief or leader (English, -master): *ŝipo*, ship; *ŝipestro*, captain; *telegrafo*, telegraph; *telegrafestro*, chief telegraphist.

-et—denotes decrease or diminution of degree: *valvo*, valve; *valveto*, tiny ("peanut") valve; *rivero*, river; *rivereto*, rivulet; *ridi*, to laugh; *rideti*, to smile.

ge-—denotes persons of both sexes: *patro*, father; *gepatroj*, parents; *sinjoro*, gentleman, Mr.; *gesinjoroj*, ladies and gentlemen.

-id—denotes a child or descendant: *kato*, a cat; *katido*, a kitten; *Izraelo*, Israel; *Izraelido*, Israelite.

-ig—denotes to make, render, cause to be: *morti*, to die; *mortigi*, to kill; *simpla*, simple; *simpligi*, to simplify.

-iĝ—denotes the action of becoming, turning to: *pala*, pale; *paliĝi*, to turn pale; *fluida*, fluid; *fluidiĝi*, to melt; *saturo*, saturation; *saturiĝi*, to become saturated.

-il—denotes the instrument by means of which an action takes place: *pafi*, to shoot; *pafilo*, rifle; *fajli*, to file; *fajlilo*, file; *sparko*, spark; *sparkilo*, spark gap.

-in—denotes the feminine gender: *koko*, a cock; *kokino*, hen; *heroo*, hero; *heroino*, heroine.

-ind—denotes worthiness, merit: *honori*, to honour; *honorinda*, honourable; *kredi*, to believe; *kredinda*, credible.

-ing—denotes that in which an object is set or put, a holder (for one object only): *kandelo*, candle; *kandelingo*, candlestick; *cigaro*, cigar; *cigaringo*, cigar-holder.

-ism—denotes a doctrine, practice, cult, ism (in this sense): *katoliko*, catholic; *katolikismo*, catholicism; *alkoholo*, alcohol; *alkoholismo*, alcoholism.

-ist—denotes a person following a given occupation, a person habitually connected with: *eksperimento*, an experiment; *eksperimentisto*, an experimenter; *elektro*, electricity; *elektristo*, electrician; *anonci*, to announce; *anoncisto*, announcer.

mal-—denotes the direct opposite of any idea: *bona*, good; *malbona*, bad; *estimi*, to esteem; *malestimi*, to despise; *alta*, high; *malalta*, low.

re-—denotes, as in English, again or back: *iri*, to go; *reiri*, to return, to go back; *doni*, to give; *redoni*, to return, to give back; *agordi*, to tune; *reagordi*, to re-tune; *radiado*, radiation; *reradiado*, re-radiation.

-uj—denotes that which contains a number or quantity of: *mono*, money; *monujo*, purse; *Turko*, a Turk; *Turkujo*, Turkey; *rezistanco*, resistance; *rezistancujo*, resistance-box.

-ul—denotes a person who is characterised by a given quality: *bela*, beautiful; *belulino*, a beauty; *sperta*, expert (adj.); *spertulo*, an expert.

-um—this syllable is amongst the suffixes as **je** is amongst prepositions—indefinite in meaning; and its use is confined to a few words, to be found in the dictionaries: *plena*, full; *plenumi*, to fulfil; *proksima*, near; *proksimuma*, approximate.

In addition to the above, a number of other affixes, chiefly of a technical nature appertaining to chemistry, botany, zoology, etc., are in more or less common use, though not yet officialised.

Such, for example, are **mono-, di-, tri, tetra-, hiper-, hipo-, -at, -it, -id, -oz, -ik** (of chemistry); **-al, -ine, -ac** (of botany); **-oid, -oin** (of botany and zoology); and the following more general affixes: **mis-** (English mis-, erroneous); **-end,** which is to be, . . . ed (*laboro farenda*, work to be done; *problemo solvenda*, problem to be solved); **-iv,** which can . . . (*bruliva*, combustible); **-oz,** containing, full of (in the material sense only), *ŝtona vojo*, a stone road, *ŝtonoza vojo*, stony road.

HINTS ON CORRELATIVE WORDS.

The table of correlative words (opposite) is worth careful study. They are made up of **5** beginnings, and **9** endings, each with a definite meaning. The following hints may help the memory:—

Beginnings:—

I—some (or other), **I**ndefinite.

KI—*wh*ich, *wh*at (corresponds to the **Kw**estion words in English beginning with *wh*).

TI—That.

ĈI—is like *each* said backwards.

NENI—is simply *NE* (no, none) with "n" added for euphony.

Endings:—

-A—is the adjectival ending.

-AL—think of "reAL reason."

-AM—think of a.m. (time in the morning).

-E—is the last letter in the English and Esperanto words.

-EL—think of "ELegant manner."

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-ES—think of "onE'S," possESsive case.
-O—the noun ending.
-OM—think of 'Ow Much, 'Ow Many.
-U—short for Unu (one), or individUal.

In a negative or interrogative sentence English substitutes *any* for *some* in the **I-** column; thus: *Ne estas iu tie*, There is not *anyone* there.

The **T-** column words may be changed from *that* to *this* by prefixing or adding the word "**ĉi**," thus: *ĉi tio, tio-ĉi*, this thing, *ĉi tie, tie-ĉi*, in this place, here.

The words ending in a vowel may take the accusative ending: *Mi havas nenion*, I have nothing. Words ending in **-A** or **-U** may take the plural: *tiuj*, those.

The **K-** column words may be followed by *ajn* (English *ever*), thus: *Kial ajn*, why ever.

EASY EXERCISES.

Translate any or all of the following exercises. For conditions see introductory remarks.

I.

agordi, to tune.
alta, high, tall.
aŭ, or.
bobeno, coil.
brili, to shine.
ĉefa, chief, principal
devi, to be obliged to, to "must."
flui, to flow.
forta, strong.
ĝis, until, as far as, up to.
inventi, to invent.
kaj, and.
krado, grid.
necesa, necessary.
patro, father.
per, by means of.
povi, to be able to.
ricevilo, receiver (receiving set).
se, if.
speco, sort, species.
suno, sun.
tago, day.
tra, through.
uzi, to use.

Note.—*Words which have already been explained, or which have sufficient resemblance to the English equivalents to be easily recognisable, have been omitted from vocabulary.*

TABLE OF CORRELATIVES.

	INDEFINITE	DEMONSTRATIVE	INTERROGATIVE OR RELATIVE	UNIVERSAL	NEGATIVE
QUALITY.	**ia** some kind of	**tia** that kind of such a....	**kia** what kind of what a....!	**ĉia** every kind of	**nenia** no kind of
MOTIVE.	**ial** for some reason	**tial** for that reason therefore, so	**kial** for what reason why	**ĉial** for every reason	**nenial** for no reason
TIME.	**iam** at some time, ever	**tiam** at that time then	**kiam** at what time when	**ĉiam** at every time always	**neniam** at no time never
PLACE.	**ie** somewhere	**tie** in that place, there	**kie** in what place where	**ĉie** everywhere	**nenie** nowhere
MANNER.	**iel** in some manner somehow	**tiel** in that manner thus, so, as	**kiel** in what manner how as	**ĉiel** in every manner	**neniel** in no manner nohow
POSSESSION.	**ies** someone's	**ties** that one's	**kies** whose	**ĉies** each one's every one's	**nenies** no one's
THING	**io** something	**tio** that thing that	**kio** what thing what	**ĉio** everything all	**nenio** nothing
QUANTITY.	**iom** some quantity somewhat	**tiom** so {much / many} as	**kiom** what quantity how much, many	**ĉiom** the whole quantity	**neniom** no quantity none
INDIVIDUALITY.	**iu** some one	**tiu** that one (person or thing)	**kiu** which one who	**ĉiu** every one each one each	**neniu** no one nobody

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Patro kaj patrino. La suno brilas en la tago. La anteno devus esti tre alta[1]. Kristala ricevilo estas tre simpla. Oni povas agordi per bobeno aŭ variometro. Se oni uzas variometron, kondensatoro ne estas necesa. Ju pli alta la anteno, des pli fortaj[2] la signaloj. Ekzistas[3] tri specoj de valvo, du-elektroda (aŭ diodo), tri-elektroda (aŭ triodo), kaj kvar-elektroda (aŭ tetradodo). Fleming inventis la diodon kaj de Forest la triodon[4]. Triodo konsistas el tri ĉefaj partoj: filamento, krado kaj plato (aŭ anodo). Elektronoj fluas el la filamento tra la krado gis la plato.

(1) Not *altan*, because verb *esti* takes nominative after it.

(2) Note plural, as this word qualifies the word *signaloj*.

(3) Translate by "There exist," word "there" understood.

(4) Accusative, as *inventis* is understood.

II.

apliki, to apply.
artefarita, artificial.
daŭre, lastingly, steadily.
inter, between, among.
inverse, inversely.
komuna, common, mutual.
kontraŭpezo, counterpoise.
kupleco, coupling.
kurento, current.
laŭ, according to.
mezuri, to measure.
oscila, oscillatory.
premo, pressure.
produkti, to produce.
proporcia, proportional.
rekte, directly.
tero, earth.

Volto estas la elektra premo kiu, daŭre aplikata al rezistanco de unu omo, produktas kurenton de unu ampero. Ampermetro estas instrumento por mezuri kurenton laŭ amperoj en cirkuito. Kontraŭpezo estas artefarita "tero." Kupleco estas mezuro de la komuna induktanco inter du oscilaj cirkuitoj. Kurento estas rekte proporcia je premo kaj inverse proporcia je rezistanco de cirkuito.

III.

beast, *besto*.
brother, *frato*.
care, to take, *zorgi*.
clean, *pura*.
conductor, *kondukilo*.
connection, *konektaĵo*.
copper, *kupro*.
ebonite, *ebonito*.
excellent, *bonega*.
experiment, *eksperimento*.
husband, *edzo*.
important, *grava*.
insulator, *izolatoro*.
internal, *interna*.
iron, *fero* (noun).
laboratory, *laborejo*.
lion, *leono*.
science, *scienco*.
solder, to, *soldi*.
than, *ol*.
while, *dum*.
wire, *fadeno*.

Sister and brother. Lions are beasts. Radio is an important science. Ebonite is an excellent insulator. Copper wire is a better electrical conductor than iron wire. Take care that every internal connection is clean and well soldered. The wife listens to the concert while the husband experiments in his laboratory.

More about Valve Testing. [R330-09

We have received several inquiries as to our method of representing the behaviour of a valve by its "lumped" characteristic, and how curves of the usual type can be obtained from it. As it chances, we have only two new valves to report on this month, so we will devote a little space to an explanation.

The lumped characteristic is based on the fact that over the greater portion of the working range the anode current of a valve depends on the anode and grid voltage in a special way. We all know that the current depends on both voltages, but the point is that the voltages enter the equations together under the form $(E_a + \mu E_g)$, or, in words: (anode volts + μ times grid volts) acts as one unit; μ, of course, is the amplification factor. It is this combined voltage that Eccles has called the "lumped voltage."

It follows that a given anode current can be got by various combinations of anode and grid voltage. If, for example, the valve has a μ of 10, and gives 3mA of current at 100 anode volts and 0 grid volts, we can get the same 3mA by 80 volts anode and +2 grid, or 110 volts anode and — 1 grid.

Now we can look for a moment at Fig. 1. This shows the lumped curve of a valve, of which the μ is 10·5. We see that at 100 volts it gives 2·1mA, while at 121 it gives 2·85mA. But since μ is 10·5, the effect of adding 21 volts on the anode is just the same as putting +2 on the grid.

In fact, if we find the current for 16, 37, 58, 79, 100, 121, 142, 163, and 184 lumped volts, the values must be the same as for a constant 100 volts on the anode, but with —4, —3, —2, —1, 0, +1, +2, +3, and +4 volts on the grid. In this way we can draw the curve A, Fig. 2. Next, if we take 30 volts off the anode, we can keep the same current by adding 30/10½ volts or +2·85 volts on the grid; so we can draw the curve for 80 volts anode by transferring every point of curve A 2·85 volts to the right, thus giving curve B. By repeating this procedure we get the complete set of curves shown in Fig. 2, which are of the well-known type.

The results obtained in this way are not, of course, quite so satisfactory as those

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obtained by direct plotting; for they depend on the valve having a constant μ over its working range, which is not always the case. Again, it is obvious that in a set of curves obtained as we have done in Fig. 2, the saturation current is constant, whereas in many cases the saturation current increases a little with the anode volts. In fact, for unduly low values, the saturation current may be very sensitive to change in anode volts. A further point is that where the grid volts become strongly positive, the large grid current not only decreases the saturation anode current, but causes a general drop in the steepness of the curve. In fact, the actual curves for the value of Fig. 2 might easily be as shown in dotted lines. But these are all conditions outside the working values of the valve *as an amplifier*; and it is still quite true to say that for working conditions curves got in this way are quite reasonably accurate.

For some purposes, notably for resistance coupling and for transmission, another form of curve has great advantages. This is a curve connecting anode volts and anode current, for a fixed grid voltage. This type of curve is a great favourite with Capt. H. J. Round, which would seem to indicate that it must have very solid advantages. It is readily seen that our "lumped" curve is in fact just such a curve, drawn for zero grid volts. Now if we want a curve of anode current against anode volts for —2 grid volts, we have to remember that 100 volts, say, with 0 grid, gives the same as 121 volts with —2 grid volts. So if we move every point of the curve 21 volts to the right we shall get a new curve for —2 grid volts; and we can repeat this procedure to get the effect of Fig. 3.

Thus we see that it is quite a simple procedure, from the lumped curve and the value of μ, to draw out for oneself a complete set of curves of either type. The reason why we throw this work upon our readers, instead of doing it ourselves, is simply to save space. It would make a very confused diagram if we drew on one sheet complete sets of curves for various filament heats, and we attach so much importance to this latter point that we prefer to utilise the available space for giving lumped curves for several values of filament voltage.

In future reports we hope to find room also for a small grid current curve, which gives useful information as to a valve's detecting properties.

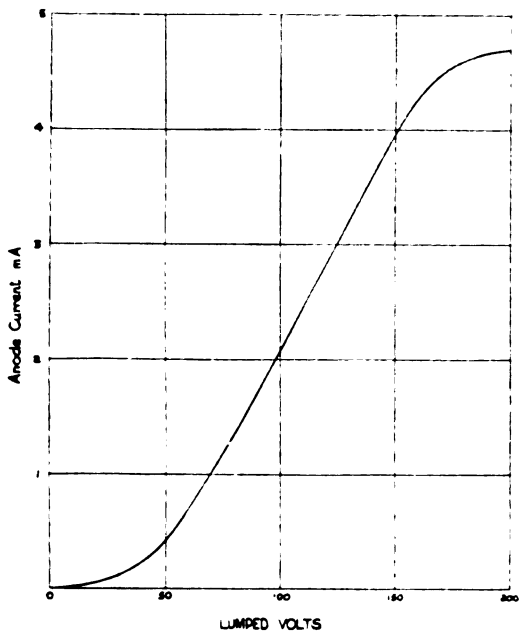

Fig. 1.

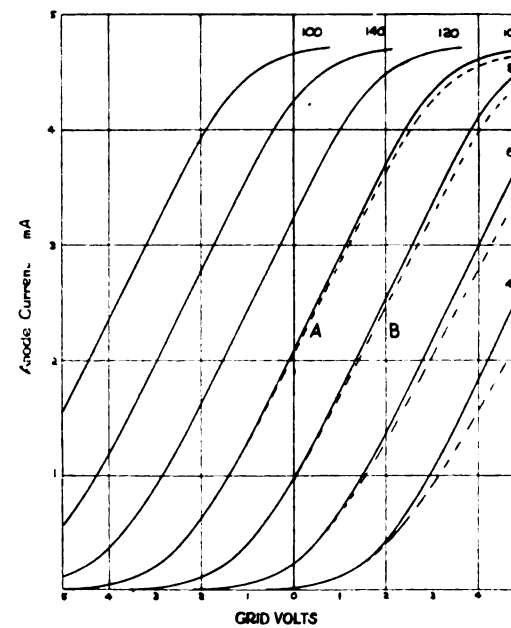

Fig. 2.

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The Radion G.P.

This is one of a series of valves made by Radions, Ltd., of Bollington, near Macclesfield; the series including both bright and dull emitters. The G.P., or general purpose valve, is rated to take ·48 amp at 3·6 to 4 volts on the filament, with 30 to 80 anode volts. As will be seen from our curves and table,

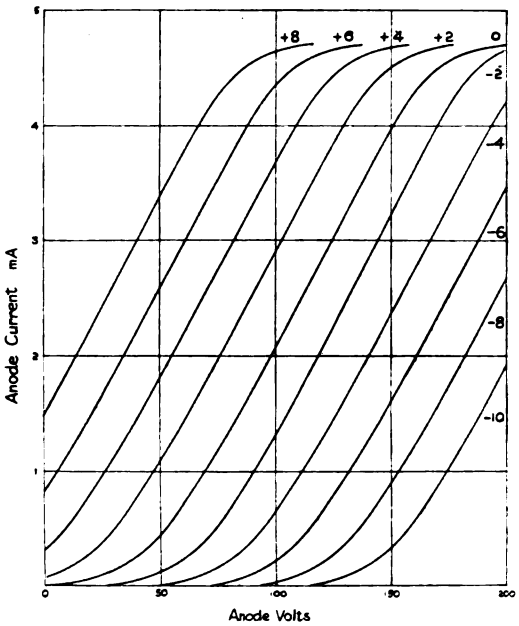

Fig. 3.

we tested it at 3·6, 3·9, 4·2, and 4·5 volts, with the results shown.

It will be seen that the output is on the low side as present-day valves go, being about equal to that of the "R" valve. Judging by the figures for filament efficiency, the filament is conservatively rated, and can be safely run up to its full rated voltage and perhaps above. The filament current is quite accurately rated.

Our table shows a fairly high μ, varying between 7·5 and 10; it is unusual to find the μ increasing with filament heat as in this instance. The anode impedance is normal for this type of valve, but below the average in view of the high amplification, with the result that the power amplification is distinctly good; a value of 5 is above the average for a general purpose valve.

In view of the fact that the valve is essentially a moderate-priced production (10s.) its finish is good, and it would appear to be excellent value. It is interesting to note that the firm undertakes the repair of valves as well as the manufacture.

Fil. volts E_f	Fil. Cur. I_f	Sat. Plate Cur. I_s	Anode Imped-ance. R_a	Voltage Ampli. μ	Power Ampli. P $\left(=\frac{1\,000\mu^2}{R_a}\right)$	Filament Efficiency. F $\left(=\frac{I_s}{\text{Watts.}}\right)$
3·6	·46	1·7	33 000	7·25	1·6	1
3·9	·48	3·1	27 000	9·0	3·0	1·6
4·2	·50	4·8	22 000	9·7	4·3	2·3
4·5	·52	7·2	19 000	10·0	5·2	3·1

The D.E.7.

In our last issue we stated in error that we were reporting the D.E.7 among other M-O valves; it was, of course, the F.E.3 that was reported. However, we have now tested out the D.E.7, which is the same valve except for the substitution of a D.E.R. type filament for the bright one of the F.E.3.

We are not actually printing the curves for this valve, for they are practically the same as for the F.E.3. The output as a "low

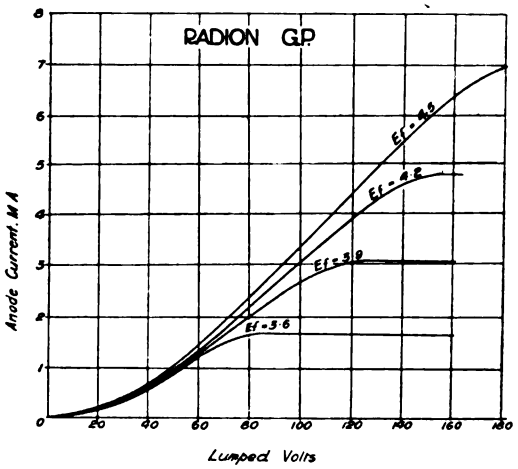

Fig. 4.

H.T." valve is a little less, but otherwise the performance is similar.

For those who are taking advantage of the excellent properties of the 4-electrode valve as dual amplifier to build a compact portable set, this dull emitter is undoubtedly most useful.

Price, 37s. 6d.

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Letters of interest to experimenters are always welcome. In publishing such communications the Editors do not necessarily endorse any technical or general statements which they may contain.

"Effective" Transmission.

The Editor, E.W. & W.E.

SIR,—In his recent articles on "Effective Transmission," Mr. Ryan makes some suggestions which can hardly be passed without comment. In the first place, how does this extraordinary conception of "broadly-tuned" C.W. transmitters and "spreading" come about? Surely C.W. is C.W., however it is generated? And by definition C.W. consists of oscillations generated continuously without decrement. There is only one kind of C.W.—namely, a sine wave with no low-frequency modulation at all. Even the presence of harmonics does not affect the present argument, for the fundamental resolves into a pure sine wave, and it, as well as each harmonic, will have the properties of a pure C.W. transmission. In any case, any exact multiple harmonics which may be produced are so far from the fundamental wave-length as not to affect a receiver tuned to this wave-length.

Any decrement in a valve transmitter must be a function of the H.T. supply or one of the well-known causes enumerated below. How can the use of high-loss H.F. circuits introduce modulation in a valve oscillator? Yet Mr. Ryan says that a poorly-designed inductance wound with fairly thin wire causes "spreading" if used with a high-power set. When Mr. Ryan made this discovery, did he make quite sure that the percentage ripple in his H.T. supply was the same when the high-loss inductance was used as when the low-loss inductance was used, and that the extra power wasted in the high-loss inductance did not increase the load of the H.T. supply sufficiently to increase the percentage of ripple in the rectified A.C. supply? Again, the direct-coupled Colpitts oscillator is accused of being "the most broadly-tuned transmitter in existence." How? And why? I experiment a good deal myself, and listen to the transmissions of many other stations, but cannot confirm such statements.

The following causes may make a transmitter take up, or appear to take up, more than its allotted band at receiving station:—

Modulation due to ripple in H.T. supply of transmitter.

Key clicks, which are only momentary.

Loose contacts in or near transmitter earth system.

Swaying of aerial.

Spacing wave if used.

Variation of frequency, or "quacking" while the key is down.

Chirps at beginning or end of key-stroke.

Modulation due to filament being heated by A.C.

Unselective receiver.

Abnormal strength or proximity of transmitting station to receiver.

In my own experience many amateurs who ought to know better entirely ignore the last two possibilities in condemning a nearby transmitting station. As far as long-distance work in this country goes, the honours seem just about equally divided between transmitters using pure C.W. and notes with a good deal of A.C. ripple in them.

Mr. Ryan seems to have performed a miracle with raw A.C. when he claims to have prevented raw A.C. transmission from "spreading beyond the inevitable band between $(N+n)$ and $(N-n)$ where N is the radio frequency and n the A.C. frequency." I should like to point out that the analysis giving only two side-bands only applies to the case where a pure C.W. carrier is modulated less than 100 per cent. Raw A.C. means that the valve is oscillating only during every other half-cycle, and the modulation is much more than 100 per cent. This makes things very complicated, and I believe that an infinite series of side-bands is formed; in any case, there is no question of being able to confine a raw A.C. transmission to as narrow a band as $2n$ by the use of tuned circuits on a wave-length as low as 200 metres.

Now for a second, and even graver issue. Mr. Ryan cites experiments purporting to show that an increase of aerial current may result in a decrease of signal strength at a distance. We are on admittedly dangerous ground here, and Mr. Ryan himself admits that he is at a loss to explain some of these apparent inconsistencies. If by the mere increase of power in the aerial system, without altering anything else, his range has really decreased, then the only conclusion is that some entirely new physical effect has been discovered which is not catered for by present-day science. I think, however, that Mr. Ryan is making mysteries worse instead of trying to clear them up. There are so many things which may alter when different transmitters are tested on different nights, and even at different times on the same night, that reliable range comparisons can only be arrived at by experiments repeated night after night with the same stations, keeping one's aerial and earth and counterpoise arrangements absolutely unchanged, as well as the wave-length. I am familiar with circumstances

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which make one think that the higher one's power, the less the range; but in my case, at any rate, I think there is always a simple reason if only it can be recognised.

Take Mr. Ryan's own case, when he says that he gave up the direct-coupled Colpitts circuit for a loose-coupled circuit, with a reduction of aerial current from 3 amps. to 2·5 amps. and an increase in range; in the Colpitts circuit there was a series condenser below the A.T.I., whereas with the loose-coupled circuit there was probably none. Now, any such change in the loading of the aerial is bound to shift the nodal point and the potential distribution along the aerial. Two things result from this: First, if the aerial ammeter is kept in the same position, it is bound to give different readings in the two cases; secondly, the radiating properties of the aerial may be considerably altered. I mention this as an example of how careful one must be to consider all the possibilities of the case before forming premature conclusions.

I think also that a little misconception may exist over the harmonic evil. Granted it is undesirable to radiate harmonics, but there is not much harm in generating them in the first place. It is well to remember that no ordinary valve can generate a pure sine wave on one frequency only unless it is working at an efficiency less than 50 per cent. The wave form of oscillations generated at high efficiency must necessarily be distorted, a condition which results in the production of an infinite series of harmonics which become progressively feebler as the order increases. But even at high efficiencies the total sum of the energies on all these is not anything like equivalent to the powerful fundamental, and a carefully-tuned loose-coupled aerial circuit should not respond to them to any serious degree. It is much best to work at high efficiency in the valve, and then to sort out the fundamental from the harmonics in this way. If the harmonics are not passed on to the aerial, they remain as wattless components in the closed circuit, and represent no expenditure of energy. The only harmonics of the aerial which exist are the odd ones, but these are not the harmonics which a C.W. transmitter puts out. The harmonics we get with a valve transmitter are those due to the valve characteristic and the distortion of the oscillatory currents through the valve. All harmonics, odd and even, are produced. Hence another of Mr. Ryan's alleged discrepancies between theory and practice disappears.

In conclusion, I should like to suggest that the many amateurs who despise theory as not in agreement with practice, should inquire more closely into their actual knowledge of theory and the precision with which they observe practical facts.

London. E. H. ROBINSON (2VW)

Intermediate H.F.

The Editor, E.W. & W.E.

SIR,—In the article "A High Power Super-Het," your contributor uses the phrase, "Intermediate H.F." I have heard of all sorts of frequencies, but this is a new one. I suggest High L.F. would be more applicable. But excuse the sarcasm. Your contributor has misunderstood the application of the word "intermediate" in this connection. It came into use for the "Super-Het" because the frequency at which amplification takes place is between H.F. and L.F., hence I.F., or approximately the band from 65 to 25 kilocycles.

Another small point. (I am great at criticism, if at nothing else.) Mr. Hugh P. Ryan states, in parentheses: "By the way, who invented condensers with metal end-plates?" The drift of the paragraph in which this occurs is somewhat obscure, and this question does not escape the general haze. However, it would appear that he does not wish for an answer in order to bestow honour where it is due, and I would therefore join issue with him. Surely such an authority as Mr. Ryan is aware of the considerable increase in efficiency accruing by the abolition of solid dielectric in the fields of coils and condensers carrying H.F. current. (The equivalent series resistance at 1 000 cycles of a badly designed ebonite end-plate condenser may be of the order of 500 ohms, whereas the figure for a "Low-loss" condenser with moving plates grounded to metal ends may be as low as 20 ohms.) But, perhaps Mr. Ryan means that a variable condenser should have end-plates of air. An excellent idea.

15, Auriol Road, London, W.14. W. J. POTTER.

[As a matter of fact, we believe that either ebonite or metal end-plates will give good results *if the design is good*. This is the important point.—Ed., E.W. & W.E.]

H.F. and L.F.

The Editor, E.W. & W.E.

SIR,—I am very interested indeed in the discussion now going on in the E.W. & W.E. regarding the respective merits of H.F. and L.F. amplification on the short waves.

So far, no one has mentioned a possible and very practicable method of obtaining additional selectivity by means of L.F. amplification. This may be brought about in two ways: (1) By using a specially designed high ratio L.F. transformer, having a decided amplification peak near 1 000 cycles. (2) By using what I believe is known as the Kooman's low frequency amplifier, which was originated in Holland, and described shortly in one of the early numbers of E.W. & W.E. In this an oscillating circuit tuned to 1 000 cycles is connected in parallel with the secondary of the intervalve transformer, and by means of a suitable reaction coil connected in the plate circuit of the valve, the L.F. valve is practically made to oscillate at 1 000 cycles.

Both these methods give a very decided amplification peak near 1 000 cycles, and if the note of the received signal is adjusted to come right on this peak, it will be amplified very strongly, while most interference, which will not be tuned to this frequency, will not be amplified nearly so much.

Several Americans have tried method (1), and report very satisfactory results. I am shortly going to experiment on method (2), and would be glad to hear from anyone who has used such a device.

With regard to the question of whether to use

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H.F. or L.F. amplification for short wave work, if one is working on schedule with a transmitting station whose wave-length is known, by all means use H.F. Both theoretically and practically it is possible to get greater sensitivity by this method, and, in this case, as much time as required can be spent in adjusting the receiver to the point of maximum sensitivity. But, on the other hand, if it is desired to search efficiently and rapidly over a wide band of wave-lengths—say, from 70 to 150 meters—it is better to use L.F. It is very much easier, and probably more efficient to cover the entire band of wave-lengths with a well-designed detector and single note magnifier, which only introduces two controls, and can therefore be rapidly adjusted to maximum sensitivity. It is interesting to note the fact that at least two out of the four English amateurs who have so far worked 2-way with New Zealand were using L.F. amplification only in their receivers.

Of course, by H.F. I do not mean the super-heterodyne, which is undoubtedly the best receiver for short waves, for those who can afford it.

Cambridge. E. J. MARTIN.

The Editor, E.W. & W.E.

SIR,—There seems to be a tendency on the part of those who advocate H.F. amplification to regard the non-H.F. enthusiasts as persons who are not clever enough to get H.F. to work on short waves. Granted that it is a difficult matter to construct an effective short wave H.F. amplifier, it is rather ridiculous to tack on a quite unnecessary collection of apparatus to one's receiver simply to demonstrate that the owner can get it to work. That it is quite unnecessary is shown by the final test of excellence—results. It does not matter at all how excellent theoretically H.F. amplification may be, or how utterly wrong L.F.; if the latter produces the results, all other arguments go for nothing.

It is hardly necessary to mention the results obtained with non-H.F. receivers, particularly in two-way working, where the greater ease in tuning scores heavily. The first two-way transatlantic working was with "O-v-1" receivers at each side. The record log of transatlantic signals (by Mr. S. K. Lewer) is obtained on O-v-1 or O-v-0. Argentine (CB8) was first reported from all parts of the country on the same type of receiver. And the last amateur feat—New Zealand—received well with two or even single valve receivers, and no H.F.

The fact is, that the most important requirement in design is no longer sensitivity, but ease in handling. Any decent single valve receiver, with an optional L.F. for bringing up weak stuff, will get practically everything going, so long as it is designed to give freedom from capacity effects, smooth reaction, fine adjustment over a large band of waves, calibrated scale, and an arrangement for very close wave-length adjustment giving precise control of the heterodyne note received, etc.

These and other features are those required to search over a wide band of very short waves, and at the same time maintain the same standard of receptiveness. Personally, I find it possible to arrange reaction control so that one can search over, say, 95-140 metres with one knob, the receiver being in its "just oscillating" condition all the time, leaving the other hand free to take down the traffic. If signals are a little weak, press the L.F. button; if QRM troubles, bring off oscillation and switch on the heterodyne wavemeter.

Most of the textbooks say that if signals are inaudible, the addition of L.F. will not bring them up. This is incorrect, as anyone will find out if he takes the trouble to try it, assuming the receiver is a good one. It must be admitted that the strength is not so great when brought out from "nothing" in this way as if H.F. had been added, but in practical work the H.F. valve takes at least several seconds to tune in to the best advantage, and by that time it may be too late.

It is quite possible that some may ask "What about the super-het.?" It is unfortunate that in most descriptions of this excellent type of receiver it is represented as being a true H.F. amplifier in the sense that the peculiar advantage of H.F. amplification—strengthening of signals before rectification—is obtained. It seldom seems to be made clear that it is simply a method of L.F. amplification which is more selective and less noisy than the usual types.* The undeniable merit of this form of receiver merely confirms the view that H.F. is unnecessary, as here we have an elaborated L.F. amplifier which preserves the essential ease in handling, and at the same time gives very great amplification without undue noise or interference. Still, the humble single valve has such a magnificent DX record to its credit that those unable to afford the "Rolls-Royce" of receivers need not greatly envy those who can.

37, Cluny Gardens, Edinburgh. MARCUS G. SCROGGIE. (5JX)

[*Our correspondent does not seem to us to be quite correct here.—ED., E.W. & W.E.]

Short-Wave Signals.

The Editor, E.W. & W.E.

SIR,—Having been successful in receiving all the short-wave signals transmitted from the Eiffel Tower during July, a short summary of the conclusions arrived at may be of interest to readers.

The signals were sent on four different wave-lengths, 115, 75, 50 and 25 metres, and the emissions were of two types:—

(1) F where the aerial functioned at its natural wave-length.
(2) H where the aerial functioned at a harmonic.

The conclusions were:—

(1) Day strength always less than night strength.
(2) Ratio of strength of F to strength of H inversely proportional to wave-length. It being unity at about 50 metres.
(3) Strength greater when there is more QRN.
(4) Impurity of wave and a spacing wave present on 50 and 25 metres.

When fading is present:—

(5) It is less on shorter wave-lengths. It is absent below 50 metres.
(6) Ratio of fading of F to fading of H inversely proportional to wave-length.
(7) It is greater when there is more QRN.

VYVYAN A. G. BROWN (6JZ).

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Sparks from the Aerial.

The Editor, E.W. & W.E.

SIR,—Having been very much interested in the comments of several observers regarding sparks from antennæ, I am impelled to offer some data of my own.

Located as we are on a large plain and far from the sea coast, thunderstorms of great energy are very common. Our antenna at W.C.A.J. is connected to earth through a S.P.D.T. switch of 100 ampères capacity. By leaving this switch open sufficiently to leave a small gap between the blade and the lower terminal, sparks from $\frac{1}{8}$ to $\frac{1}{2}$ inch have repeatedly been observed with with thunderstorms at a distance of three to ten miles, also in hail and snowstorms, and often in winter when dry snow is being blown about by a high wind. When thunderstorms are overhead, experience has taught us to keep away from the lightning switch, as the antenna has twice been struck by lightning, splitting the insulators and fusing the wires, the second time fusing the switch blade into the clip.

In connection with some experiments on the electrical charges on falling rain, I have recently had opportunity to measure the potentials induced by atmospheric charges on an insulated metal deck which is being used as a collector. The deck is of galvanised iron, 10 by 14 feet, and mounted on the flat roof of a building thirty feet high adjoining the Physical Laboratory. A highly insulated wire connects the deck to one terminal of a sensitive galvanometer, the other galvanometer terminal going to earth. On a clear summer day the deck has a potential of —·01 to —·05 volts, the higher values usually being recorded about noon. In hot, sultry or cloudy weather, potentials of nearly +1 volt have been recorded, the sign of the charge having a tendency to vacillate with the approach of a storm. Lightning discharges from distant clouds induce in the deck potentials of 50 to 1 000 volts, the sign being more frequently negative than positive for a distant storm, and changing to principally positive as the cloud approaches. With heavy lightning directly overhead, potentials of +6 000 volts have been recorded, and on a number of occasions the instrument was thrown entirely off the scale, indicating even greater potentials.

We hope to publish later a more extended report of the present investigation, but the figures cited will give some idea of the magnitude of the potentials involved.

Department of Physics, J. C. JENSEN.
Nebraska Wesleyan University.

New Zealand.

The Editor, E.W. & W.E.

SIR,—With reference to recent announcements *re* reception of New Zealand amateurs, the following information of G5NN's work may be of interest to you.

Z4AA, Z4AG, Z4AK were first heard at 5NN on Monday morning, October 20th, at 6.42 a.m. Constant reception, often with phones on the table, has been carried out on each succeeding morning to date. On Sunday, October 26th, Z4AA reported to G5NN very strong. Two-way working was not established owing to sunrise. On Thursday, October 30th, Z4AQ called G5NN, and reported signals very QSA with slight QSS. Signals readable all the period that they were audible.

Transmitter at G5NN consists of Meissner circuit. Full wave rectification with M.T.1 valves. Oscillator two T·250 valves in parallel. Input 200 watts, radiation 1·85A on 97 metres. Aerial 56 ft. high, 6 wire cage. Counterpoise 6 wire, 12 ft. above ground. Receiver, Burndept Ultra III., using detector (D.E.Q.) and one L.F. (D.E.5) only. Reception when working New Zealand always carried out without aerial to avoid atmospherics.

S. Norwood. J. H. D. RIDLEY.

A Correction.

The Editor, E.W. & W.E.

SIR,—I have just noticed an error in my article on "Some Measurements on a Broadcast Receiver," p. 88 of the present number, and I should be glad if I may be allowed to correct it.

The object of the large shunting condenser in the anode circuit of the valve voltmeters is to reduce the impedance of the circuit external to the valve to a negligible quantity at all frequencies, thus rendering the calibration independent of frequency. This is very necessary as the instrument is most conveniently calibrated on 50*f*. A.C. and may be used, perhaps, on $3 \times 10^6 f$.

G. W. SUTTON.

Tribute to Amateurs.

The following grateful tribute to the value of the work of American wireless amateurs was broadcast from the Naval Research Laboratory at Bellerne, D.C. on Navy Day by authority of Mr. Curtis Wilbur, Secretary of the U.S. Navy. It refers to the assistance given by amateurs in maintaining wireless communication during the flight of the Shenandoah.

"To Amateur Radio Operators of the United States.

"The co-operation of the amateur radio operators with the Naval Research Laboratory has resulted in increasing the communication efficiency of our Navy. The new long distance communication records made by the Shenandoah are a direct result of your co-operation.

"Interest, such as you have shown in the Navy in time of peace is the country's best guarantee of our Navy's readiness when called upon for our country's defence.

"It seems appropriate, therefore, that on Navy Day, which coincides with the completion of the wonderful transcontinental flight of the Shenandoah, I congratulate and thank you for your contributions towards a better and more efficient Navy.

"CURTIS D. WILBUR."

We do not, unfortunately, hear of any activities on the part of the R.S.G.B., which might have led to a similar official appreciation in this country.

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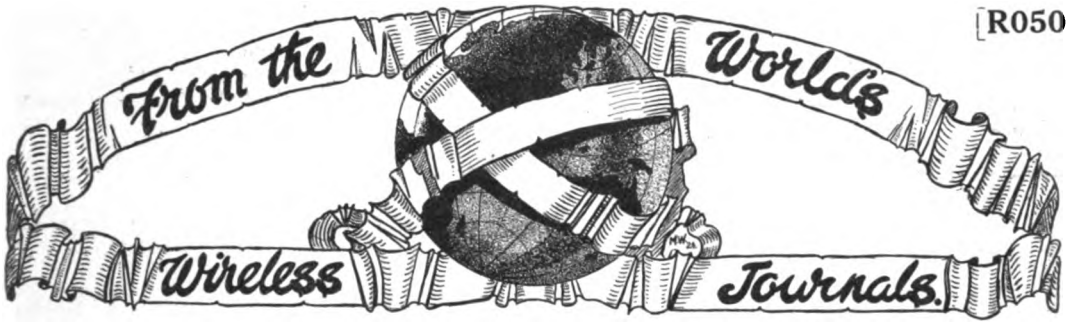

R000.—GENERAL.

R008.—Digests of United States Patents Relating to Radio Telegraphy and Telephony Issued. June to August, 1924.—J. B. Brady (*Proc. I.R.E.*, Oct., 1924.)

An interesting regular feature of the Proceedings of the Institute of Radio Engineers giving an idea of what has been recently patented in the U.S.A.

R009·2.—My Radio Experience in the Far North.—Donald H. Mix (*Q.S.T.*, Nov., 1924.)

The operator of the "Bowdoin" expedition gives an account of short-wave communication conditions throughout the various phases of the expedition. Though semi-topical, the account contains practical data which form a distinct addition to our knowledge of short-wave radio work.

R114.—Discovery of a Place Where No Static Could be Heard in August.—R. H. Marriott (*Proc. I.R.E.*, Oct., 1924.)

A point was found off the Alaska coast where no atmospherics were heard during a period of six days in August, 1921. Such spots have been found to be dead spots with respect to certain transmitting stations, while they are favourable for the reception of other stations. The observed effects are ascribed by the observers to the mountainous nature of the Alaska coast.

R582.—The Transmission of Pictures by Wire and Wireless.—(*W. World*, Oct. 29.)

A short *résumé* of a paper on the subject recently read before the Royal Photographic Society by Mr. Thorne Baker, F.R.P.S.

R100.—GENERAL PRINCIPLES AND THEORY.

R113.—Unsolved Problems of Wireless.—R. H. Barfield, M.Sc. (*W. World*, Nov. 12.)

A paper read before the Radio Society of Great Britain dealing with the irregularities experienced in the propagation of wireless waves: namely, the bending of waves round the curvature of the earth's surface, night ranges, fading and variations in directional bearings at night.

R113.—More About Effective Transmission.—H. N. Ryan (*Exp. W.*, Nov., 1924.)

A topically-written article on some observations on the relation between the range of a transmitting station on short wave-lengths, and the power and circuital arrangements used.

R134·4.—An Analysis of Two Triode Circuits.—J. H. Morecroft and A. G. Jensen (*Proc. I.R.E.*, Oct., 1924).

An analytical examination of two typical triode circuits used for obtaining regeneration by mutual induction, with the idea of testing the results by experiments. Measurements made on circuits operating at 1 000 cycles confirm the theoretically derived relations to a remarkable degree of precision.

R141.—An Easy Way to Calculate Circuits.—P. K. Turner (*Exp. W.*, Nov., 1924).

An explanation in simple language of how the impedance, reactance, etc. of circuits containing resistance, inductance and capacity may be calculated with the use of "j"; the methods being reduced to simple arithmetic and no knowledge of higher mathematics being necessary.

R200.—MEASUREMENTS AND STANDARDISATION.

R113·2.—Etude sur les Irrégularités de Propagation des Ondes Courtes.—M. Lardy (*Onde Elec.*, Oct., 1924).

Second part of a description of some experiments made on the variation of signal strength over various parts of the day and night. More signal strength curves are given and some data has also been obtained on "dead spots" and the effect of topographical conditions.

R131.—Experimental Determination of the Fundamental Dynamic Characteristics of a Triode.—Eijiro Takagishi (*Proc. I.R.E.*, Oct., 1924).

By picking out the fundamental component only from the distorted current in a triode while functioning, the writer has found, first, new forms of dynamic characteristics for a triode, and secondly that the grid current may reach a large value and that a

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certain constant depending on the emission merits attention. Some experiments have been carried out relative to the voltage amplification factor, for which a new expression has been found.

R220.—THE MEASUREMENT OF SMALL CAPACITIES. —(*W. World*, Nov. 12.)

A bridge method of measuring small capacities against a variable standard capacity.

R220-240.—A NEON LAMP METHOD OF COMPARING CAPACITIES AND HIGH RESISTANCES.—W. Clarkson, M.Sc., and J. Taylor, B.Sc. (*Exp. W.*, Nov., 1924).

Various uses of the flashing method of comparing capacities and resistances are described. Experimentally-determined graphs are reproduced showing that a linear relation exists between the flashing period and the supply resistance to the lamp or the capacity across it.

R250.—ETALONNAGE D'UN AMPERMÉTRE EN HAUTE FRÉQUENCE.—M. Clayeux (*Onde Elec.*, Oct., 1924).

Brief description of a method of calibrating a H.F. ammeter against a D.C. ammeter by placing each in turn in series with the filament of a thermionic valve, the filament being heated with D.C. when the D.C. instrument is used, and with H.F. when the H.F. instrument is used. The currents in both cases are adjusted to the same thermal value as indicated by the emission of the filament, which is indicated by a plate milliammeter.

R261.—SOME MEASUREMENTS ON A BROADCAST RECEIVER.—G. W. Sutton, B.Sc. (*Exp. W.*, Nov., 1924).

Description of some experiments in which a Moullin voltmeter was employed to measure received voltage, amplification, etc., on a broadcast receiver.

R270.—A METHOD OF MEASURING RADIO FIELD INTENSITIES AND ATMOSPHERIC DISTURBANCES.—L. W. Austin and E. B. Judson (*Proc. I.R.E.*, Oct., 1924).

A method of measuring signal strength by the use of a telephone comparator. For determinations on a C.W. signal the heterodyne note is adjusted to the same pitch as that of a standard tuning-fork generator, the output of the latter being adjusted by means of a potential divider to give the same intensity in a pair of telephones as the heterodyne note of the signal. For measuring atmospheric disturbances the standard generator currents passed into the telephones are broken into morse signals by keying and the intensity varied until the signals are just readable through the atmospherics.

R300.—APPARATUS AND EQUIPMENT.

R134·2.—NOTE SUR LA DETECTION PAR LES LAMPES À TROIS ELECTRODES.—Messrs. Davaud and Petit (*Onde Elec.*, Oct., 1924).

A simple and concise description of the action of grid-leak and condenser rectification.

R139.—HELIUM TUBES.—F. S. McCullough (*Q.S.T.*, Nov., 1924).

Short note on thermionic power valves containing pure helium. It is stated that the presence of helium reduces the impedance of the valve and assists cooling. Such valves are said to be in successful operation at several American broadcasting stations.

R320.—ANTENNAS FOR SHORT WAVES.—H. F. Mason (*Q.S.T.*, Nov., 1924).

Short article pointing out that short waves permit the experimenter to realise his ideals in design, as the magnitude of aerials for short wavelengths need not be large.

R342·6.—INTÉRESSANTE UTILIZATION D'UN ETAGE D'AMPLIFICATION À RESONANCE.—P. Girardin (*R. Elec.*, Oct. 10, 1924).

Description of the use of a three-electrode valve as a means of coupling between a receiving set and an aerial. The circuit described would appear to amount to very much the same thing as one stage of tuned anode H.F. amplification.

R342·701.—THE PERFORMANCE AND PROPERTIES OF TELEPHONIC FREQUENCY INTERVALVE TRANSFORMERS.—D. W. Dye, B.Sc. (*Exp. W.*, Nov., 1924).

Concluding part of an important article on the electrical properties of intervalve transformers, including inductance, impedance, resistance, capacity, ratio of windings, etc.

R343.—THE ONE-CONTROL SUPERHETERODYNE.—J. L. McLaughlin (*Q.S.T.*, Nov., 1924).

Detailed description of a supersonic heterodyne receiver in which the local oscillator and the tuner are simultaneously varied by one knob. In order to make this feasible the proportions of inductance to capacity in the two circuits have been ingeniously chosen so that the numerical frequency-difference between the local oscillator and tuner is constant over the whole range of adjustment.

R343.—THE ONE-VALVE SET.—P. K. Turner (*Exp. W.*, Nov., 1924).

An article dealing with the operation and important details in the ordinary one-valve regenerative detector.

R343.—THE SUPER-HETERODYNE: ITS ORIGIN, DEVELOPMENT AND SOME RECENT IMPROVEMENTS.—E. H. Armstrong (*Proc. I.R.E.*, Oct., 1924).

Some improvements in super-heterodyne receivers, particularly in the reduction of the number of valves used. Wherever possible a valve is made to perform at least two functions. For instance, the separate oscillator may be abolished and its function filled by the first valve in the set. Dual amplification is made use of where possible. The work described is the result of an effort to bring this type of receiver within the demands of the pocket and manipulative ability of the ordinary broadcast listener. This paper would appear to be one of the few substantial contributions to the subject since Armstrong's original paper in 1919.

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R344.—A HIGH-EFFICIENCY VACUUM TUBE OSCILLATING CIRCUIT.—D. C. Prince and F. B. Vodges (*Proc. I.R.E.*, Oct., 1924).

Description of a modified push-pull circuit in which approximately square waves of current are passed through the valves alternately. High efficiency is obtained by superimposing upon the grid circuit a voltage proportional to current variations in the plate circuit. The circuit gives high output and high efficiency without shortening the life of the valves.

R344.—PARALLEL OPERATION OF POWER TUBES.—J. H. Turnbull (*Q.S.T.*, Nov., 1924).

Account of some of the troubles experienced in running oscillator valves in parallel, with particular references to parasitic oscillations on wave-lengths of only a few metres. Experiments made by the writer indicate how these parasitic effects are caused and how they may be suppressed.

R344·3.—TRANSMITTING EQUIPMENT FOR RADIO TELEPHONE BROADCASTING.—Edward L. Nelson (*Proc. I.R.E.*, Oct., 1924).

A description of the standardised Western Electric broadcasting apparatus which has been installed and used in a number of American broadcasting stations. The technical demands of broadcasting as regards quality of reproduction, etc , are dealt with. It is interesting to note that condenser microphones have been standardised in the Western Electric Co.'s equipment as well as the more familiar carbon granule type.

R344·4.—PRACTICAL SHORT WAVE TRANSMITTERS. —(*Q.S.T.*, Nov., 1924.)

A few details of a valve transmitter for wave-lengths of 20-22 metres.

R351.—OSCILLATING CRYSTALS.—O. Lossev (*W. World*, Oct. 22).

Some observations are given on the properties of the contacts of detecting and oscillating crystals, including the effect of temperature on a generating contact, variation of resistance with temperature, luminescence at the point of contact, the waveform of the generated oscillations and the generating characteristic of tinstone.

R356.—NOTES ON POWER TRANSFORMER DESIGN.—A. Castellain, B.Sc. (*Exp. W.*, Nov., 1924).

The notes comprise information enabling the reader to design the core and windings of a power transformer for high voltage on commercial frequencies.

R375. — SINGLE POINT DETECTORS. — James Strachan, F.Inst.P. (*W. World*, Nov. 12, 1924).

Account of some interesting experiments, showing how detecting contacts may be obtained with a number of everyday substances.

R375·09.—COHERERS AND CONTACT DETECTORS.—James Strachan, F.Inst.P. (*W. World*, Oct. 29, 1924).

A short account is given of the history of various coherers and detectors and the theory of their action. The author deals with the subject of coherers and their relationship to modern crystal detectors.

R386.—SELECTIVE RECEIVING CIRCUITS.—N. W. McLachlan, D.Sc. (*W. World*, Nov. 12, 1924).

An account of the use of resonant circuits and cascaded circuits to effect selective reception.

R400.—SYSTEMS OF WORKING.

R460.—DUPLEX TELEPHONY.—P. P. Eckersley, M.I.E.E. (*Exp. W.*, Nov., 1924).

An article outlining the problems of duplex telephony and describing a few methods of achieving and operating it.

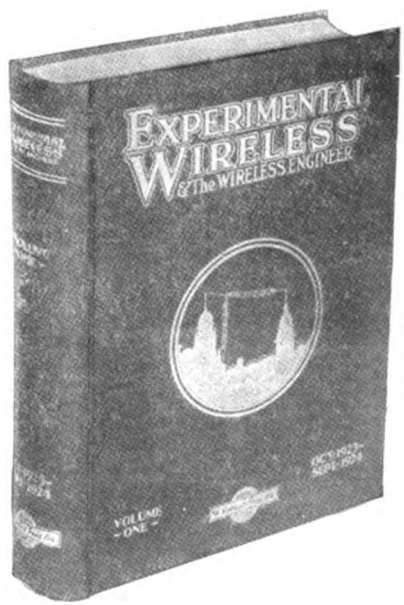
R500.—APPLICATIONS AND USES.

R510.—RECHERCHES RADIOGONIOMÉTRIQUES SUR LA MARCHE DES TYPHONS.—E. Gherzi, S.J. (*Onde Elec.*, Oct., 1924).

A series of experiments made at the Zikawei Observatory, Shanghai, for the purpose of studying the relation between atmospherics and the movements of typhoons. Tables of data are given showing directions of typhoon-centres, as given by the meteorological service, and simultaneous bearings of maximum atmospheric disturbances, as determined by a frame aerial.

An Omission.

By an unfortunate omission, which we regret, the name of Mr. H. Emmons did not appear beneath his article, "A Compact High-Power Super-Het," in last month's E.W. & W.E. Mr. Emmons' description of his set has attracted much interest.



The photograph gives an idea of the handsome appearance of the bound First Volume of "E.W. & W.E."

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(The following notes are based on information supplied by Mr. Eric Potter Patent Agent, Lonsdale Chambers, 27, Chancery Lane, W.C.2)

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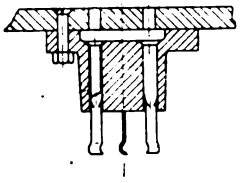
INCREASED RESILIENCY.

Patent No. 219,826, Application Date, September 4, 1923, granted to A. P. Welch, describes a valve-holder suitable for mounting on the under side of a panel. Holes are drilled in the top of the panel so that they register with the valve sockets and thus enable the valve to be inserted. The object of the invention is to prevent the risk of short circuits between the various elements of the valve holder, and also to prevent the valve from being burnt out if an attempt is made to insert it incorrectly. The idea is illustrated by the accompanying figure and reminds us of the Mullard "Safety Disc."



A GAS-FILLED VALVE.

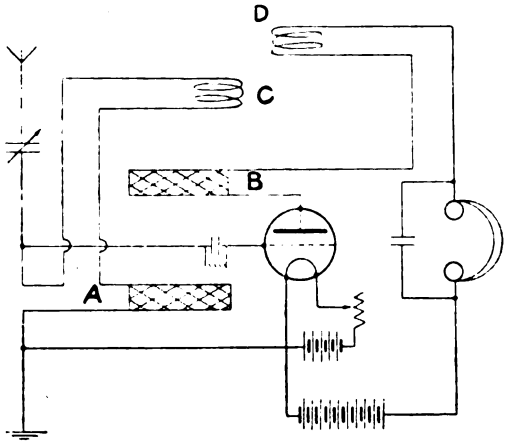
W. R. Bullimore describes in Patent No. 218,116, Application Date, July 17, 1923 (which is a patent of addition to No. 192,462, October 31, 1921), a gas-filled, or soft, valve in which means are provided to combat the effects of ionisation present in the ordinary type of valve. Normally it is found that when ionisation occurs, the ions take a "curved polar path between the filament and the anode, thus destroying the effect of the control of the grid." The inventor endeavours to avoid this effect by employing a spherical anode and grid, the arrangement of the filament also being almost spherical. The specification mentions the use of helium at a pressure of 0·6 mm. of mercury.

A DOUBLE FILAMENT VALVE.

A. P. Portway has been granted Patent No. 218,784, Application Date, May 2, 1923, for a three-electrode valve which contains two filaments. The valve is further fitted with two caps, each carrying four pins. One filament is connected to one cap, and the other filament is connected to the other cap, the grid and anode being common to each. When one filament burns out, the valve is removed from the holder and merely inverted so as to bring the other filament into use. An insulating cover is provided for the cap not in use to prevent accidental short circuit.

A REFINEMENT IN COUPLING.

J. Scott-Taggart describes in Patent No. 218,105, Application Date, January 2, 1923, a system of improved coupling. When two large inductances are coupled together, the inventor states that the slightest movement of one coil with respect to the other results in a very large change of coupling, the adjustment being far too coarse for most purposes. A small inductance is therefore connected in series or parallel with each of the two



main inductances, the variation of coupling being made between the two small inductances. This is illustrated in the figure in which A and B are the main inductances and C and D the subsidiary coils between which the variation of coupling is effected. The idea of coupling only a small part of an inductance to another inductance is, of course, quite old, and in many cases is sufficient when the total coupling has not to be very great.

HEAT RADIATION.

P. W. Baker has been granted Patent No. 220,124, Application Date, June 27, 1923, for a rheostat in which the resistance element is wound on a metal core to assist in the distribution and radiation of heat. It is specially designed for panel use and is mounted on a flat, metal plate, the other side of which carries an insulated terminal bar.

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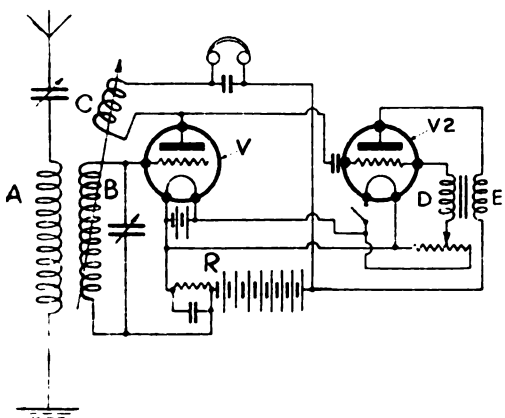
PREVENTION OF OSCILLATION.

A very interesting scheme is detailed in Patent No. 218,336, Application Date, January 4, 1923, granted to Norman Lee, John Ree and Radio Communication Co., Ltd. The idea obviously relates to broadcast receivers and has as its object the prevention of interference by oscillation and radiation. Two arrangements are described, but that employing a subsidiary valve (shown in the accompanying illustration) will be dealt with. The valve, with its associated tuning circuits A, B, and reaction coil C, is simply an ordinary, single-valve reaction circuit, suitable for short wave reception.

It will be seen that the anode of the valve V is coupled by a small condenser to the grid of valve V2. This is associated with a grid coil D and an anode coil E, and the grid potential is determined by a potentiometer. The coils D and E and the potentiometer are so adjusted that the valve does not normally generate continuous oscillations. The coils are so chosen that should the valve oscillate, the oscillations would be of a comparatively low frequency. If the reaction coil C of the



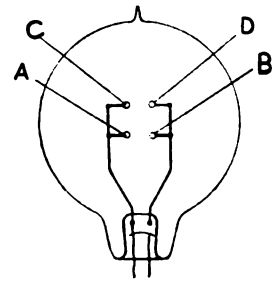
broadcast receiver is badly adjusted, so that the receiving valve V commences to oscillate, potentials of considerable value will be set up between the anode and earth and will be communicated to the grid of the valve V2. These potentials will be of sufficient magnitude to cause the valve to oscillate at a low frequency.

It will be seen that the anode circuit of the valve includes a resistance R, and accordingly these comparatively strong low frequency oscillations will cause big potentials to be set up across the resistance. This resistance, however, is in the grid circuit of the receiving valve, and will therefore communicate the potentials to the grid, completely wiping out the original high frequency oscillations. The low frequency oscillations will continue until they are stopped by opening the filament switch of the valve V2.

The idea is very ingenious, but would appear to require very careful design and original adjustment. Much interesting subject matter is included in the specification which it is not possible to mention here. In another arrangement the scheme is worked with only one valve, but would appear to be far more critical in adjustment.

A NEW DISCHARGE TUBE.

The accompanying illustration shows an improved form of discharge-tube described in Patent No. 199,732, Convention Date, June 21, 1922, granted to Naamlooze Vennootschap Philips' Gloeilampenfabrieken. It has been found that owing to volatilisation the electrodes are apt to disintegrate, thereby increasing the distance between them. This means that the starting potential for the particular tube will have to be increased as time goes on; and if only a limited voltage is available, it means that the tube will become useless after a certain time. This trouble has been eliminated by the use of two or more sets of electrodes (AB and CD), the distance between each pair being substantially the same. It is thus found that when one set becomes useless, the next will come into operation. The idea reminds us of the multiple-point spa:king-plug with which our readers are no doubt amiliar.

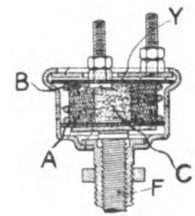


EFFICIENT CONTACT.

W. J. Davis and the Edison Swan Electric Co., Ltd. ha. been granted Patent No. 218,063, Application Date, May 8, 1923, for a rheostat of the ordinary type in which the contact arm is so constructed that it makes efficient contact with the resistance element owing to the fact that the two contact surfaces are suitably related. In other words, a slightly-concave, springy contact is used to bear upon the ordinary spiral resistance element.

THE "MICROSTAT" RESISTANCE.

It appears from Patent No. 218,523, Application Dates, August 23, 1923 and January 22, 1924, that H. A. Yoward is the inventor of the well-known "Microstat" type of resistance. The construction is exceeding simple and comprises a compressible felt disc A, with a central hole filled with carbon granules C, which are kept in position by two plates X and Y. Between the two plates X and Y there is a spiral spring C.



The felt pad is enclosed in a metal case, at one end of which there is a screwed rod F, which is connected to the operating knob. On turning the rod, the felt pad will be compressed, and with it the carbon granules, the resistance of which will decrease. The connections are taken, of course, from the two metal plates, between which the resistance is caused to vary. On unscrewing the rod F, the pressure on the granules will be released, and the felt pad will be returned to its original condition by the spiral spring C.

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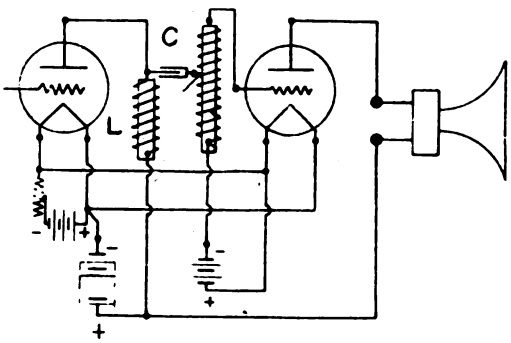
A PECULIAR LOW FREQUENCY COUPLING.

E. A. Graham and W. J. Ricketts describe in Patent No. 218,066, Application Date, May 9, 1923, a rather peculiar form of valve coupling, which is illustrated in the accompanying figure. The specification states that the invention has for its object high voltage amplification with very little distortion in wave form. Referring to the figure, it will be seen that the anode circuit of one valve contains a choke L, and is coupled to the subsequent valve by a condenser C. The condenser is not connected directly to the grid of the valve, but is taken to a tapping on A which constitutes an auto-coupled transformer.



The illustration includes a loud-speaker, so it would appear that the circuit is intended for speech frequencies, but no indication is given of the values of either the choke or the auto-transformer windings. The specification states that there is little change in wave form, but this would seem to be directly determined by the actual windings of the components of the circuits. It would be interesting to examine mathematically the network L C A. The specification also provides for the shunting of the primary and secondary of the auto-transformer by high resistances, which further complicates the analysis of the operation of the device.

AN OLD IDEA.

R. H. Winter has been granted Patent No. 219,234, Application Date, December 6, 1923, in which is claimed a valve-holder so constructed that it may be attached to a panel so that the valve is parallel with the plane of the panel. The patent is essentially of a constructional nature, as there is obviously nothing novel in mounting a valve in the position indicated. We seem to remember using a valve-holder of this type on a certain Army set years ago, but we are, of course, open to correction.

A NEW RHEOSTAT.

Patent No. 218,020, Application Date, April 3, 1923, granted to C. Seymour and G. W. Harris, describes a rheostat in which there are two contact arms bearing on a resistance element wound in drum form, both the arms and the drum being capable of rotation. In another modification two or more drums are employed. The rheostat is obviously capable of being used in a variety of ways, but for general work we see no special advantages. No doubt the inventors had some special object in view.

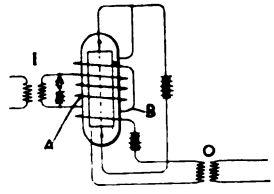
A FOOL-PROOF SET.

Patent No. 211,513, Convention Date, February 19, 1923, granted to the Marconi Co., Ltd. is a document which should be carefully studied by everybody who is connected with the manufacture of wireless sets. The description of the invention occupies some nine pages, and no less than thirty-one illustrations are required. The essence of the invention is involved in the first claim, which reads: "The combination of a single adjusting member, a receiving circuit having tuning elements . . . comprising a continuously variable capacity and inductance, the elements determining the reactance of the said tuning elements throughout their adjustment being co-operatively proportioned in a manner such that the relation between the square root of the product of the inductance into the capacity, and the movement of the adjusting member is substantially a straight line function, and a dial co-operatively associated with said adjusting elements and having substantially equal wave-length differences."

The specification describes how this is accomplished in a multi-valve receiver employing a separate heterodyne, and the construction of the receiver seems almost to include the use of every known device of spade, tuning square or other law condensers, gearing, linking and switching, the combination of which constitutes one claim of the invention.

A MAGNETRON AMPLIFIER.

The illustration shows a new magnetron amplification circuit covered by Patent No. 199,742, Convention Date, June 26, 1922, held by the British Thomson-Houston Co., Ltd. The magnetising field is provided as usual by the coil A, to which the currents to be amplified are supplied by means of the input transformer I. The anode circuit contains an output transformer O, the primary of which is in series with a coil B, adjacent to the magnetising coil A. The coil is so connected that the anode current tends to oppose that in the magnetising circuit.



It will be seen that if the magnetising current is increased by the initial currents to be amplified, the anode current will decrease. But this current passes through the coil B, which opposes the magnetising current, and consequently the effective value of the magnetising current will be materially strengthened. This obviously results in a much greater amplification, and the arrangement is comparable with the usual regenerative coupling in a three-electrode valve.

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EXPERIMENTAL WIRELESS & The WIRELESS ENGINEER

VOL. II. JANUARY, 1925. No. 16.

Editorial Views.

Appreciation.

AMONG our tasks this month is the pleasant one of expressing to many readers hearty thanks for very kind letters of appreciation. We feel particularly indebted to readers who have written to signify their approval of our series on the B.S. Dewey extension for classifying wireless matters, and of our Esperanto grammar.

We are particularly glad to receive these letters because (to be perfectly frank) it was with a certain diffidence that we introduced these subjects. For our own part, we were quite convinced of their value; but we were uncertain whether our readers would appreciate articles not dealing directly with wireless technical matters.

However, there is no doubt that these innovations are popular, and we shall see that they are kept in view in future issues. The Dewey extension, of course, will not be complete for a few months yet; and as regards Esperanto we have plans to continue our journal's usefulness to those readers interested. In this issue we publish an English-Esperanto dictionary of wireless technical terms, and before long we hope to publish its natural supplement, an Esperanto-English dictionary.

Last, but not least, we have to thank some readers who, in their close study of E.W. & W.E., have come across errors, and have pointed them out to us. In spite of the utmost care, it seems almost impossible to avoid these from time to time. Even the most skilled compositors are not necessarily skilled mathematicians nor wireless experts, and it only takes a very small accident (from the printing point of view) to make a large error in mathematical work.

Such accidents occur in most journalistic work, and in many cases are discreetly ignored. But in a journal of our standing it is, we feel, of importance that they should be corrected, and we are always grateful to correspondents who point them out.

Crystals.

As indicated in this page of our last issue, we have now tested out some crystals on the new lines then suggested, and the results will be found further on. As those of our readers who have not had experience of quantitative work may be interested to have some idea of what it involves, we have also included in this issue a fairly full description of how the preliminary work was carried through and what it meant.

It must be realised, of course, that the tests which we report cannot claim to be a final verdict on the merits of these crystals. Firstly, individual samples of the same crystal vary enormously; and secondly, individual points on the same sample sometimes vary equally widely. Conditions of time available limit us to testing a few points on one sample, and we are unable to state that these points necessarily give a fair average indication.

Thirdly, there is the question as to whether the method, as a whole, is a sound one giving a valid result! Our own opinion, naturally, is that the method is sound, or we should not have adopted it. But there are very many points to be considered in measurements of this kind, and we quite expect to

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receive some criticism of the method—in fact we hope for it if it is constructive.

One critic, whose opinions we value highly, and whose hitherto unpublished work on crystals is of quite exceptional value, has written: " . . . I think you are tackling a rather desperate proposition. . . ." So do we! But it will not be the first we have tried, and we hope not the last.

On the other hand, there may be many readers who will take up the attitude of another friendly critic: "Why all this fuss about crystals? They're dying fast, anyway!" (It might be noted that this friend is connected with the manufacture of valves.) This raises a point of fundamental importance. It is true that much of the amateur work of to-day—the serious long-distance amateur work—is done on valve detectors. But there is an increasing proportion of those whose experiments lie in the direction of the distortionless reception of telephony, and for this purpose the crystal has important advantages. Again, there are those of our readers who are engineers practically engaged in the design of broadcast sets: and the crystal is of undoubted importance here. In our opinion there is only one cause which may cause a drop in the use of crystals: high price owing to scarcity!

Receiving Aerials.

Our readers will undoubtedly be greatly interested in the description by Dr. Smith-Rose and Mr. Colebrook of their experiments on P.M.G. aerials, earths, and counterpoises, at Teddington. For a personal reason we are glad to note therein some remarks as to the extreme difficulty in mathematical analysis of the conditions in a receiving aerial—for we have tried it and given it up in despair. Apart from this, there are three most interesting conclusions: the suggestion—it is only put forward as such—that there may be an optimum height for a P.M.G. aerial, and that a 100 ft. vertical one is not necessarily the best; the great advantage of a counterpoise for reception; and the fact that a quite efficient counterpoise can be erected under "garden" conditions.

Measurement.

Two articles in this issue are devoted to means of getting the greatest amount of work out of measuring instruments. This is, we consider, a very important subject, for it is an unfortunate fact that such instruments are usually expensive.

We forget who was the great scientist who stated, "He discovers who measures." But he must have been one of the very greatest. It is more and more evident as time goes on that progress in science is essentially a matter of measurement. It is not until we have accurate quantitative data on any subject that we can check our hypotheses and proceed to deeper investigation. As a classical modern example we have the work of Einstein—entirely based on the apparently contradictory results of a measurement of great difficulty, and so far-reaching in its results as to be likely to alter our whole point of view in looking at fundamentals, although it may not directly affect everyday life.

There is a natural disposition in amateur or "hobby" work of any kind to go out after spectacular results. But, interesting and useful as such work is, we doubt whether its result as regards general progress is any more important than the sometimes laborious job of delving after exact quantitative data. It is delightful to get loud-speaker results all over the house, and dull to try and measure the actual power in the loud-speaker. But sometimes the latter is the more important task.

For this reason we have always given freely of our space to matter connected with measurement, and articles showing how measurement can be done at moderate financial cost are especially valuable.

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The Arrangement of Wireless Books and Information.

Part IV: R300—Apparatus and Equipment. [R025·4

This month we come to R300, the division dealing with Apparatus and Equipment generally. This has been a difficult section. There is no doubt that at the moment America as a whole and England as a whole are approaching the problems of wireless from rather different angles. They are investigating problems that we are leaving alone, and *vice versa*. The natural result is that certain branches of the subject, of great interest to us, are dismissed rather lightly in the B.S. extension, while others are dealt with perhaps more fully than we should have handled them.

In re-writing this section, therefore, we have extended some parts considerably.

R300 Apparatus and Equipment.

For matters of theory, reference should be made to R100, while descriptions of operation, and certain other aspects, will be found under R400, Systems.

Under the "general" heading, R300 to R309, will come, as usual, such matters as are conveniently dealt with under the "form" division (see E.W. & W.E., Oct., p. 760). The heading R310 is also left blank.

R320 Aerial design and construction.

In the B.S. Extension, two headings are given under R320, viz.:—
R320·6 Aerial switches.
R320·8 Masts.

For the same reasons as indicated in dealing with R201 last month (E.W. & W.E., p. 131)—possibility of confusion with the form division—we suggest that these numbers be allowed to drop, and we have found room elsewhere for such items.

R321 Ordinary elevated aerials.
*R321·8 Masts and towers.
*R321·9 Ammeters, switchgear, protective devices, etc.
R323 Earth aerials (*i.e.*, lying on ground) and underground aerials (see also R536, Mining, in connection with the latter). The beverage aerial is dealt with here.
R324 Frame aerials.
R325 Directional aerials generally.
R325·1 D.F. aerials for reception—Bellini-Tosi, Robinson, and frames designed for this purpose.
·6 "Directive" aerials, *i.e.*, those designed for directed transmission, excepting Beam systems, which will be found under R329.
R326 Earths and earth connections, including counterpoise design.
*R326·5 counterpoises.
R327 Artificial aerials.
R328 Multiple-tuned aerials.
R329 Other special aerials.
*R329·1 Beam systems.

R330 Thermionic Valves: design and construction. (For theory, see R130.)

This section deals with the valve itself. For valve sets and circuits, and the *use* of valves generally, see R340.

*R330·04 The design of valves. Effect of constructional design on performance, etc.

R331 Manufacture of valves.
*R331·1 Construction of electrodes, and metal-work generally.

*** These subdivisions are proposed by us as a tentative further extension.**

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* ·2 Filament manufacture, including thoriating, coating, etc.
* ·3 Bulb and foot work, and glass work generally.
* ·4 Assembly, sealing, etc.
* ·5 Evacuation: for pumps, etc., see under R800; 533·85, Vacuum apparatus.
* ·51 Bombardment and similar processes.
* ·52 "Getters": phosphorus, magnesium, and similar devices.

R332 Two-electrode valves.
R333 Three-electrode valves.
R334 Four-electrode valves.
*R335 "Soft" valves of ordinary types.
*R336 Thermionic valves working on special principles, differing from the normal, *e.g.*, Magnetron, Dynatron, Sodion, etc. Note that Neon tubes, "S"-tubes, etc., are hardly thermionic valves. They should really go under R800, at 621·327; but it seems more convenient to find room for them here, so we suggest doing so as in the next class.
*R337 Special valve-like devices, not depending essentially on thermionic electron emission, *e.g.*, Neon tubes, "S"-tubes. We propose to assign the Mercury Arc to this class on the ground of convenience, although it is an open question whether it should not logically be placed under R332.

R340 Valve apparatus and circuits.

In this class, we only deal with those parts of the apparatus actually and intimately concerned with the valve. The following sections (R350-380) deal with other parts of such installations.

R341 Devices using the valve as a rectifier.
*R341·1 Detectors. (For theory see R134.)
*R341·6 Rectifiers for supply purposes. (For theory, see R149. See also R355, where devices using such valves are discussed.)

R342 Valve amplifiers. (For theory, see R132.)
R342·1-·3 Couplings.
R342·1 Inductive coupling generally.
* ·11 Choke coupling.
·15 Transformer coupling.
R342·2 Resistance coupling.
·3 Capacity coupling.
R342·4-·7 Types of amplifier.
·4 Reflex amplifiers.
·5 Power amplifiers.
·6 Radio-frequency amplifiers (including "intermediate" amplifiers for supersonic sets).
·7 Audio-frequency amplifiers.

R343 Valve receiving sets.
This heading is specially suited to special sets in which the distinguishing features cannot be separated into "detector," "amplifier," etc.
*R343·4 Superregenerators. (For theory, see R134·45.)
·5 Heterodyne sets. (For theory, see R134·7.)
* ·6 Supersonic sets. (For theory, see R134·75.)
·7 Sets using A.C. supply.

R344 Valve generators. (For theory, see R133.)
*R344·1 Audio-frequency oscillators.
* ·2 Radio-frequency oscillators of simple type. (For accurate wavemeters, see R212.)
·3 Transmitting sets.
·4 Extra short-wave oscillators.
·5 Oscillators for A.C. supply.
·6 High-power valve generators.
·7 Multivibrators and similar instruments.

R345 Modulators. (For theory, and different systems of modulation, see R135.)
R346 Complete telephony sets.
R348 Uses of valves in wire systems (telephone repeaters, etc.), and other devices.

*** These subdivisions are proposed by us as a tentative further extension.**

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R350 Transmitting apparatus, apart from valves and valve circuits. (For theory, see R150.)

In many cases information on these subjects will go more conveniently under R400. Generally, details of apparatus and components will go here, the functioning of the whole installation under R400, and its theory under R150.

R351 Simple Oscillators, including oscillating crystals. Such crystals, of the American quartz type, are also dealt with under R800: 537·65, Piezo-Electric Phenomena.

R352 Spark gaps. (See also R152 and R411.)

R352·2 Quenched gaps.

·4 Synchronous rotary gaps.

·6 Asynchronous gaps.

·8 Timed spark gaps for C.W. (See also R424.)

R353 Arcs. (See also R153 and R422.)

R354 H.F. Alternators. (See also R154 and R421.)

When dealing with Goldschmidt alternators note also R357.

R355 High-voltage generators.

Details of such apparatus really form a well-known part of electrical engineering, and might accordingly be placed under R800: 621·313. But as they are of considerable importance, and special work has been done in providing high direct voltage for wireless purposes, we have inserted an extension.

*R355·1 Simple D.C. generators.

* ·2 D.C. to D.C. converters and motor-generators.

* ·3 A.C. to D.C. converters.

* ·4 Systems utilising A.C.

* ·41 Alternators.

* ·42 D.C. to A.C. rotary converters and motor-generators.

* ·43 Make-and-break systems for converting to A.C., including rotary commutators.

* ·5 Re-conversion to D.C.

This is, of course, rectification, and is also dealt with elsewhere. See especially R341·6.

* ·51 Synchronous commutators.

* ·52 Arc rectifiers.

* ·54 Electrolytic rectifiers.

* ·55 Rectifiers using valves.

R356 Transformers (power).

Intervalve and radio-frequency transformers are dealt with elsewhere.

R356·5 Induction coils.

R357 Frequency transformers.

R358 Protective devices.

R359 Automatic transmitters.

R360 Receiving sets, complete.

This should be kept for descriptions, etc., of complete sets: details of apparatus will be found under R370.

R370 Receiving apparatus, apart from the valve circuits. (For theory, see R160.)

See also the note under R350 above, with regard to entries under R400.

R373 Amplifiers.

R373·1 The magnetic amplifier.

·2 Microphone amplifiers.

R374 Crystal Detectors. Note that oscillating crystals are dealt with under R351.

R374·1 Theory of action. This applies to such questions as: why crystals rectify? The theory of the action of rectifiers in a circuit is covered under R149.

R374·2 Crystals in practice; notes on use and so forth.

R374·3 Balanced crystal circuits.

*R374·4 Other unusual crystal circuits.

*** These subdivisions are proposed by us as a tentative further extension.**

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*R374·5 Details of various types of crystal: galena, carborundum, etc.
R375 Miscellaneous detectors.
R375·1 The magnetic detector.
·2 Coherers.
·3 Electrolytic detectors.
R376 Telephones (including loud-speakers).
R376·3 Loud-speakers.
R377 Recording devices.
R377·1 Photographic recorders.
·2 The jet relay.
·3 Electro-magnetic recorders.
·4 The Telegraphone.
·5 Phonograph recording.
·6 Automatic printers.
R378 Audibility meters.

R380 Parts of circuits, components, etc.

It should be noted that the vacant numbers towards the end of this section must be kept more or less open for new devices as they come to light.

R381 Condensers. Precision condensers will be found under R228, standards.
*R381·1 Qualities of a condenser: power factor, constancy, strength, etc.
* ·2 Fixed condensers.
* ·3 Variable condensers, interleaved semi-circular type.
* ·4 Interleaved variable condensers with special shaped plates.
* ·5 Other types of variable condenser.

R382 Inductors.
We have adopted the word used in the B.S. extension—a far better word than "inductance" to describe an actual component.
*R382·1 Qualities of an inductor: power factor, constancy, strength, etc.
* ·2 Single-layer coils.
* ·3 Pile-wound coils.
·4 Open-wound coils (honeycomb, Morecroft, etc.).
·5 Couplers, H.F. transformers, etc.
* ·7 Variometers.
* ·8 Tappings, dead-end switches, etc.

R383 Resistors.
(See note to "Inductors" above *re* use of word.)
R383·1 Grid-leaks.
* ·2 Anode resistances.
* ·3 Filament Rheostats.
* ·4 Special materials (other than wire), for resistance manufacture.

R384 Special meters.
Meters generally are covered under R200, but as that section is devoted largely to *methods* of measurement, room is also found here for description of complete instruments as components or accessories.
R384·1 Wave-meters.
·3 Frequency-meters.
·5 Decremeters.
* ·6 Ammeters.
* ·7 Voltmeters.
R385 Modulating devices, including keys, etc.
R385·1 Keys.
·2 Buzzers.
·3 Rotary interrupters.
·5 Microphones.
* ·51 Carbon microphones.
* ·52 Magnetophone types.
* ·53 Condenser types.
* ·54 Jet and similar types for high current.
R386 Filters.
R387 Sundries.
R387·1 Shields.
·5 Earthing of apparatus.
·7 Insulators.
R388 Oscillographs.

*** These subdivisions are proposed by us as a tentative further extension.**

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The Inter-Electrode Capacities of a Valve.

By H. J. Barton Chapple, Wh.Sch., B.Sc. (Hons.), A.C.G.I., D.I.C., A.M.I.E.E.

[R131

This article deals with a subject of great importance to all research Workers.

THE inter-electrode capacities in a thermionic valve often have considerable influence on the design of accurate receiving and transmitting sets on short waves, while for quantitative measurements at high frequencies a knowledge of these values becomes imperative. Again, the capacities in the valve holder itself often account for peculiar results, and this matter calls for great care in the design of a good holder with highly efficient insulating material in order to obviate the possibility of a low resistance leakage path. In many receiving sets signals are obtained when the grid-leak is absent, and this is often accounted for by the fact that a leakage path for the electrons is provided in the holder itself between A and B, Fig. 1, so that R is unnecessary. Measurements have been made by the writer where the resistance between A and B has only been of the order of two or three megohms, from which obvious conclusions may be drawn. Other cases will no doubt suggest themselves to the reader.

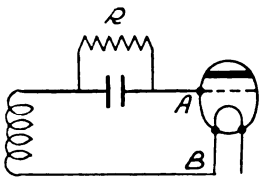

Fig. 1.

Using a simple capacity resistance bridge to balance out the quantities in question, varying results were secured. With valve holders of reputed make, however, the resistance previously mentioned was of a very high order, above 20 megohms, but the capacities were quite appreciable. Referring to Fig. 2, which shows a plan of the holder, the following average results were obtained.

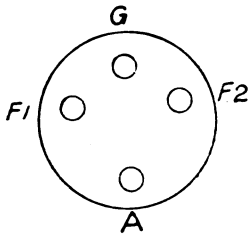

Fig. 2.

Between	A & F_1	Capacity	= 34$\mu\mu$F
,,	A & F_2	,,	= 34 ,,
,,	G & F_1	,,	= 35 ,,
,,	G & F_2	,,	= 35 ,,
,,	A & G	,,	= 30 ,,

Upon inserting an ordinary R type thermionic valve into the sockets and repeating the measurements, average inter electrode capacities were found to be, after subtracting the capacity due to the holder :—

Between	A & F_1	Capacity	= 0$\mu\mu$F
,,	A & F_2	,,	= 6 ,,
,,	G & F_1	,,	= 8 ,,
,,	G & F_2	,,	= 9 ,,
,,	A & G	,,	= 10 ,,

The total capacities of holder and thermionic valve, therefore, should be borne in mind when making such calculations for wireless circuits as indicated by P. K. Turner in the November issue of E.W. & W.E.

To ascertain what modification was introduced by employing a low capacity type valve, viz. :—Marconi's V24, new measurements were made with a good quality holder—Fig. 3.

The capacities found were :—

Between	A & F_1	Capacity	= 21$\mu\mu$F
,,	A & F_2	,,	= 23 ,,
,,	G & F_1	,,	= 21 ,,
,,	G & F_2	,,	= 23 ,,
,,	A & G	,,	= 23 ,,

For the valve alone the only capacity that could be detected was that between A & G, of 3$\mu\mu$F, so that the advantage of this type is readily appreciated.

In an ordinary valve the capacities are due mainly to the manner in which the connections are brought out at the "pinch." Complications are possible owing to F_1 and F_2 being joined by a low resistance path when the valve is inserted, thus giving parallel capacities.

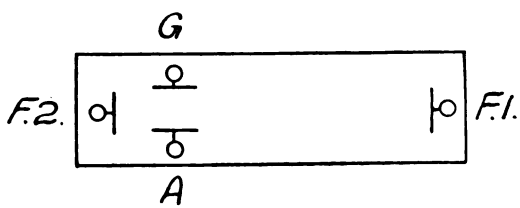

Fig. 3.

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A Test for Crystals. [R374

We have given rather full details of the work of devising and carrying out this test, as we think readers may be surprised at the large amount of time and labour required for what seems at first a very simple business.

FOR many months now we have been faced with the problem of finding a fair test for the comparative merits of crystals—and a very difficult problem it is; even now our solution is only a rough and ready one.

It was obvious from the first that the simple method of putting the crystal in circuit and listening, or even measuring the output, was unfair; for firstly it indicates rather whether the crystal suits the circuit than whether it is a good one; and secondly there is no guarantee that the incoming signal will always be of the same strength.

For some time we have used a method, based on direct current characteristics, by which we found the proportion between the currents in the two directions at various voltages. But while this gave a certain amount of information it was far from satisfactory. Many samples of galena gave extraordinarily good results in this way. A ratio of 2 000 to 1 between the two currents was found once or twice, and 500 to 1 was common. Thus, as far as reverse current is concerned, we may consider picked galena practically perfect, and we decided to find a method which would test other characteristics as well.

We considered the idea of applying a measured H.F. current, and noting the D.C. current given out. But further consideration showed that this was hardly a fair test; for a high-resistance crystal would absorb more power than a low for the same input current, and would hence be favoured by the test.

Finally, we decided on applying measured H.F. power, finding the output power, and rating the crystal on its actual efficiency.

It was thought that there might be some constants for each crystal which would give a complete guide to its quality. But some confidential results which have come into our hands indicate that the problems of naming such constants, and of finding them in practice, are so excessively difficult as to be impracticable for our purpose, which necessitates a reasonably quick test. The same results showed quite clearly that the behaviour of a crystal depends very largely on the "output load"—the resistance of telephones, etc., across it; so that really every crystal should be tested, not only with varying applied voltage, but with varying load.

Now (as will be explained later) the actual test is not an absolutely simple matter. To test out a crystal on the lines indicated above would involve a trial at say five voltages, each with five loads, or 25 tests for each point; and as one must try at least five points the work would be impossibly heavy.

It must also be realised that, strictly speaking, the efficiency of a crystal in giving large D.C. output from steady H.F. is *not* the same as its efficiency in giving audio-frequency output from modulated input. But without the resources of a full-blown laboratory the latter test is quite impossible; it needs an instrument to measure less than one microamp of current at audio-frequency, among other things. Actually, good D.C. and audio-frequency efficiency are usually found together, so that the former is at any rate an indication of the latter.

So we have compromised as follows. A fixed load of 10 000 ohms is used, roughly corresponding to the impedance of ordinary high resistance 'phones. Five different points, taken as they come, are tested at an applied voltage of ·5. Another point, of good quality as compared with the average of the five, is tested at various voltages varying from 0·1 to 1 volt. All the work is done at one wave-length of 377 metres, or 795 000 cycles—this wave is chosen as it gives ω, or $2\pi \times$ frequency, equal to 5×10^6.

Some Preliminary Tasks.

As we have indicated, the test is simply to measure the input and output power. We wonder whether all our readers, especially the less technical, realise quite what that has involved!

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The output power is easy. The load resistance is known, and the current can be measured. The calculation is too simple to be transferred to the Appendix at the end: it is simply (calling P_0 the output power)

$$P_0 = I_d^2 R_l,$$

where I_d is the steady detector current and R_l the load resistance.

The input power is a far more tricky problem. The trouble is that the detector must be tested at an input voltage such as is likely to be applied to it in service, otherwise the results are useless. In practice this means a voltage of ·1 to 1 volt. But at these voltages the crystal appears (as we shall show) to have a resistance of 5 000 ohms or so, which obviously means that we must measure a current of 20 microamps at radio-frequency. This cannot be done with any reasonably robust and cheap instruments. So we gave up all idea of measuring the actual crystal current, and fell back on another method. This was to find the "equivalent series resistance" of the detector when across a given tuned circuit, from which the power is easily found.

The general idea of this method is easily explained. The fundamental circuit is shown in Fig. 1. Here the source sets up an H.F. voltage in L, and a current flows through L and C, also through R_0, which represents the resistance of the coil. If now the coupling and source are unaltered, the actual E.M.F. induced is constant.

As the circuit is tuned the reactances of L and C cancel one another, and the current depends only on the resistance. If now we insert a resistance R_a the current will decrease, and it can easily be shown that if instead we close the switch B, placing the resistance S across the condenser, the current will again decrease. This seems contradictory at first, but is none the less true, the reason being that the flow of current through S means a loss of power, which naturally diminishes the current : if there were no resistance at all in any part of the circuit, there would be no power loss, and no limit to the current in it.

Since either a series or a shunt resistance, or in fact any source of power loss, causes a drop in current, one can find a series resistance which would give the same drop of current as any power loss, and this is its "equivalent series resistance." Its value depends not only on how big is the source of loss, but also on the frequency.

Summing up the last few paragraphs, the detector absorbs power from the circuit, and hence causes a drop in the current from which, if the circuit resistance is known, the input power can be calculated. The details of calculation are given in the appendix.

In actual practice, bearing in mind that the voltage is to be ·1 to 1 across the circuit, and that the usual sizes of condenser C have a reactance of some hundreds of ohms at 377 metres, the current in the oscillating circuit, though much larger than that through the detector itself, will still be only a milliamp or less, and this is not too easy to measure. So instead we decided to

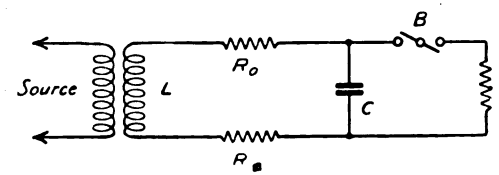

Fig. 1.

measure the voltage itself, which is just as useful if the capacity of the condenser is known accurately.

Thus we have now converted our problem to that of measuring voltages of say ·1 to 1 volt at radio-frequency. Luckily, the Moullin voltmeter enables us to do this easily.

The Moullin Voltmeter.

This simple device was described quite recently in our pages;* but for those who missed this article one need only explain that it is simply a calibrated valve detector. Two types may be used. The more sensitive has a leak and grid condenser, but has the disadvantage of putting a quite measurable load or power loss in the circuit. The other or "anode" type uses (as its name indicates) anode rectification, and if proper grid bias is used takes so little power as to be negligible. It is, however, less sensitive. Our own gives reliable readings from about ·3 to 3·6 volts, and by a simple trick we used it to measure voltages as low as ·1 applied to the detector.

But before going into this, we will describe the calibration of the Moullin, as it had to

* G. W. Sutton, B.Sc. "Some Measurements on a Broadcast Receiver." *E.W. & W.E.*, Nov., 1924.

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be done before the tests could be commenced. Incidentally, the calibration of the Moullin itself involved a previous job, so we will take that first: it was the fairly simple one of calibrating a sensitive thermo-junction.

Calibrating the H.F. Milliammeter.

This was done on direct current. A dry cell, a high variable resistance (2 000 ohms max.), a D.C. milliammeter, and the thermo-junction were connected in series, with a Paul Unipivot microammeter across the junction. Actually, a reversing switch was inserted, as sometimes a thermo-junction gives different readings when the same current goes through it in opposite directions, in which case the average reading is the correct one. The circuit was that of Fig. 2.

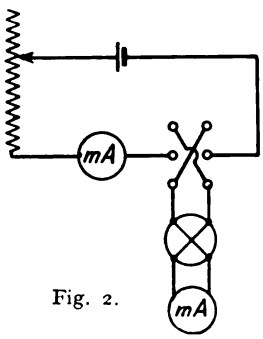

Fig. 2.

The resistance was adjusted so that the milliammeter read each half-milliamp from 1 to 9, at which latter figure the microammeter was full over. At each value the reversing switch was thrown over. The whole was repeated thrice, with extra checks at low currents, and careful note taken of all readings. A curve was then drawn giving actual mA for all micro ammeter readings. The inductance and capacity of the junction is so low that the calibration can probably be considered accurate to ½ 1 per cent. even at radio-frequencies, if the rest of the circuit is handled skilfully as regards screening, etc. But for the particular job of calibrating the Moullin we only wanted 100 cycles or so.

An Audio-Frequency Source.

The next task was to produce this. Luckily, it did not involve much work. We had a simple separate heterodyne, using spare plug-in transformers from our set, as its coils. We also use the same type of 4-pin socket for our L.F. transformers; and on plugging one in, with a condenser of ·001 across the secondary, at once got somewhere about 75 cycles. The oscillator has the plate circuit broken for an output coil, but as it only uses one Wecovalve the output was not enough. But we connected it to a two-stage L.F. amplifier (one D.E.5 and one L.S.5) which gave plenty.

Calibrating the Moullin.

The output was connected as in Fig. 3. A telephone transformer stepped down to get fairly large current, which was applied to a rheostat R (20 ohms by 1 ohm steps) and another B, which was actually a Post Office Bridge, using the low resistance coils (20 ohms by 1 ohm). These resistances are not, of course, absolutely pure resistance: they have small inductance and capacity; but at 75 to 100 cycles this is negligible. The two were adjusted by steps, keeping the sum constant. This kept a constant load and steady current in the thermo-junction, and the current shown, multiplied by each value of the resistance B, gave the actual voltage on the Moullin corresponding to the deflection in the plate circuit galvo (a Paul Unipivot). Actually, the same instrument was switched from one position to the other. With a Mullard D.F. Ora valve, and the plate and grid voltages shown, about 2·6 volts on the filament gave 10μA plate current, which was adopted as the zero value.

The Detector Test Circuit.

At last we were ready to think about

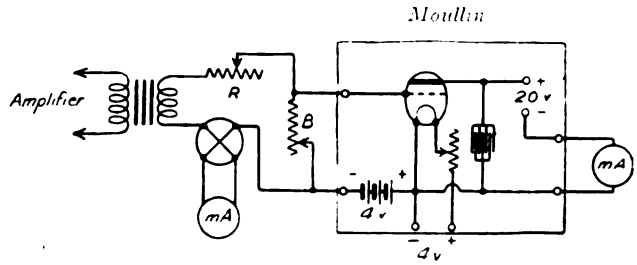

Fig. 3.

detector tests, and after some preliminary experiments we set up the circuit shown in Fig. 4. Various points call for notice. The coil is in two parts, of 40 and 80μH, and by means of switch A the crystal can be cut out altogether, or put across either all or one-third of the total inductance. The voltmeter is always across the whole.

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In this way one can get a step-down, the minimum measurable voltage of ·3 volt across the whole giving ·1 volt across the

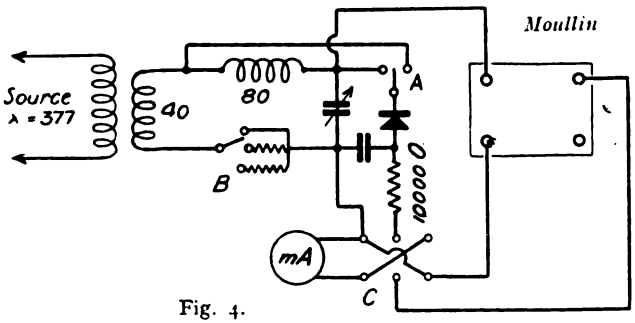

Fig. 4.

crystal circuit. Switch B cuts out or inserts a resistance in the oscillating circuit. This is necessary to find the circuit's own resistance, and is also useful for some crystals. The resistances are 42 Eureka, straight, so as to be of practically the same resistance at H.F. as for D.C., on which they were measured. Switch C was made necessary by the fact that only the one microammeter is at present available to measure both crystal current and the plate current of the voltmeter.

The Procedure.

One begins operations by finding the resistance of the oscillating circuit. The crystal is switched out, the voltmeter put on, and the circuit accurately tuned; and the source adjusted to give a full deflection with no resistance at B. When a resistance is inserted here, the voltage falls off, as already explained. If the circuit were already of fairly high resistance an ohm or two at B would make little difference; but if it is of low resistance the same "ohm or two" will cause a large drop. Hence the voltages with and without resistance enable one to calculate the circuit resistance (see Appendix).

Next the crystal is switched in and the tuning adjusted. The coupling to the source is adjusted to give ·5 volt on the crystal, and the crystal current read. Without altering the source, the crystal is switched out, the circuit re-tuned, and the voltage noted. The change of voltage between "crystal in" and "crystal out" gives the key to the input power; the crystal current itself, flowing through the 10 000 ohms load, represents the output power. This is repeated for five consecutive points taken just as they come. Then another good point is found and tested not only at ·5 volt, but at 1, ·7, ·5, ·3, ·2 and ·1 volts.

It may be stated at once that it is extremely tricky to get really close results, even more so than is always the case in high-frequency resistance measurements. Outside of a high-class laboratory, an accuracy of 10 per cent. is probably about what one can get. But as will be seen from the results, this is much better than nothing. In addition to the actual efficiency, it is useful to have an idea of the high-frequency resistance of the crystal, for a crystal of low input resistance may, even if very efficient, be undesirable, as it damps the receiving circuit heavily, and may give unduly flat tuning. The method of calculating this is also shown in the Appendix.

APPENDIX.

High-Frequency Resistance Measurement.

In the circuit of Fig. 5, if the source is supplying power at a frequency f, and $\omega = 2\pi f$ as usual, then E, the induced E.M.F. in L, is

$$E = j\omega M I_1 \quad .. \quad .. \quad (1)$$

and if M and I_1 are maintained constant during a test, E is constant.

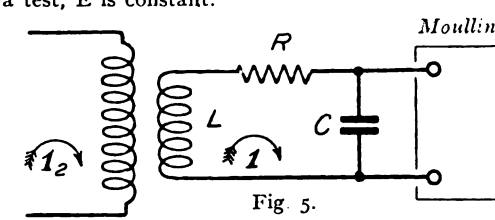

Fig. 5.

If the circuit is tuned

$$I = \frac{E}{R} \quad .. \quad .. \quad .. \quad (2)$$

If E_m is the voltage at the meter,

$$E_m = \frac{I}{j\omega C} = \frac{E}{j\omega CR} \quad .. \quad .. \quad (3)$$

$$\text{Hence } R = \frac{E}{j\omega C}\frac{I}{E_m} = A\frac{I}{E_m} \quad .. \quad .. \quad (4)$$

where A is constant.

Now R may be the resistance of the circuit itself (R_0) or may contain an added resistance. If we take two measurements, one with R_0 only, and one with a known R_1 in addition, we have

$$R_0 = \frac{A}{E_0} \quad .. \quad .. \quad .. \quad (5)$$

$$R_0 + R_1 = \frac{A}{E_1} \quad .. \quad .. \quad (6)$$

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Substituting from (5) in (6)

$$R_1 + \frac{A}{E_0} = \frac{A}{E_1} \quad .. \quad .. \quad (7)$$

$$R_1 = A\left(\frac{1}{E_1} - \frac{1}{E_0}\right) \quad .. \quad .. \quad (8)$$

$$A = \frac{R_1 E_1 E_0}{E_0 - E_1} \quad .. \quad .. \quad (9)$$

inserting this in (5)

$$R_0 = \frac{A}{E_0} = \frac{E_1}{E_0 - E_1} R_1 \quad .. \quad .. \quad (10)$$

In practice, one reads with several values of R_1, and the tabular calculation for a typical case is shown in the following table :—

RESISTANCE OF CIRCUIT.

(35-Turn Coil, Condenser and Wiring.)

R_1	E_1	$\frac{1}{E}$	diff. $\frac{1}{E}$	diff. R_1	$\frac{\text{diff. } R_1}{\text{diff. } 1/E} = A$	$\frac{\text{av. } A}{E} = R_0 + R_1$	R_0
0	3·60	·278				3·08	3·08
			·049	·59	12·0		
·59	3·06	·327				3·62	3·03
			·112	1·15	10·25		
1·74	2·28	·439				4·87	3·13
			·387	4·26	11·0		
6·00	1·21	·826				9·16	3·16
					av. A 11·08		av. R_0 3·10

This may be called an excellent result, as it can easily be proved, from the amount of variation in the various values for R_0, that the probable error of the average, 3·10, is ± ·02, so that the proportionate error is ·65 of 1 per cent.

Detector Efficiency.

The first matter, the effective resistance thrown *into* the circuit by putting the detector *across* it, is got by a simple transposition of equation (10) above; for R_0 is supposed to have been found, and we want R_1, or R_a as we shall call it.

We already have $R_0 = \frac{E_1}{E_0 - E_1} R_1 \quad .. \quad .. \quad (10)$

so $R_a = \frac{E_0 - E_1}{E_1} R_0 \quad .. \quad .. \quad .. \quad .. \quad (11)$

Now if P_1 = input power,

$$P_1 = R_a I^2 \quad .. \quad .. \quad .. \quad (12)$$

but, from equation (3)

$$I = j\omega C E_m \quad .. \quad .. \quad .. \quad (13)$$

we may drop the j, as no question of phase arises, so

$$P_1 = R_a(\omega C E_m)^2 \quad .. \quad .. \quad (14)$$

also, if P_0 is output power,

$$P_0 = I_d^2 R_d \quad .. \quad .. \quad (15)$$

and η = efficiency $= \frac{P_0}{P_1} \quad .. \quad .. \quad .. \quad (16)$

Lastly, a resistance R_a, in series with a condenser C or inductance L, is equivalent to a resistance S across it, for a frequency f ($\omega = 2\pi f$), when

$$S = \frac{1}{(\omega C)^2 R_a} \text{ or } = \frac{(\omega L)^2}{R_a} \quad .. \quad .. \quad (17)$$

provided that R_a is small compared with $\frac{1}{\omega C}$ or ωL.

The following is a typical calculation; in actual practice, of course, it would form one table.

The value of ω was 5×10^6, and the resistance of circuit itself 6·5 ohms. Capacity of tuning condenser ·0004,

so that $\omega C = \frac{1}{500} = 2 \times 10^{-3}$.

With detector across both coils, E_m is adjusted to 1. I_d found to be 85μA. E_0 (*i.e.*, voltage on switching out detector and retuning) 2·35. To keep E_0 down, both tests were made with 26·3 extra ohms in circuit, giving 32·8 in all.

$$E_0 - E_m = 1{\cdot}35$$

$$\frac{E_0 - E_m}{E_m} = 1{\cdot}35$$

$R_a = 1{\cdot}35 R_0 = 1{\cdot}35 \times 32{\cdot}8 = 44{\cdot}2$

$\omega C E_m = 2 \times 10^{-3}$

$(\omega C E_m)^2 = 4 \times 10^{-6}$

$P_1 = 44{\cdot}2 \times 4 \times 10^{-6} = 177 \times 10^{-6}$

$R_d = 10\,000 = 10^4$

$I_d = 85\mu A = 8{\cdot}5 \times 10^{-5}$

$P_0 = I_d^2 R_d = 72{\cdot}2 \times 10^{-10} \times 10^4 = 72{\cdot}2 \times 10^{-6}$

$\eta = \frac{P_0}{P_1} = \frac{72{\cdot}2}{177} = 40\%$

$S = \frac{1}{(\omega C)^2 R_a} = \frac{250\,000}{44{\cdot}2} = 5\,650\ \Omega.$

In the other tests the detector was across only one-third of the inductance, so that $E_m = 3E_d$. This only affects the calculation of S.

$E_m = 2{\cdot}1$ ($E_d = {\cdot}7$), $I = 50\mu A$, $E_0 = 3{\cdot}33$, circuit resistance 6·5 Ω.

$E_0 - E_m = 1{\cdot}23$.

$\frac{E_0 - E_m}{E_m} = {\cdot}58$

$R_a = {\cdot}58 \times 6{\cdot}5 = 3{\cdot}8$

$\omega C E_m = 2 \times 10^{-3} \times 2{\cdot}1 = 4{\cdot}2 \times 10^{-3}$

$(\omega C E_m)^2 = 17{\cdot}7 \times 10^{-6}$

$P_1 = 3{\cdot}8 \times 17{\cdot}7 \times 10^{-6} = 67 \times 10^{-6}$

$R_d = 10\,000$

$P_0 = (5 \times 10^{-5})^2 \times 10^4 = 25 \times 10^{-6}$

$\eta = 37\%$

As regards S, we must remember that it is across only one-third of the total inductance. We know the total value of ωL, because, the circuit being tuned, it must equal $\frac{1}{\omega C}$;

so ωL (total) = 500.

$\omega L_d = \frac{500}{3}$ where L_d is that part across the detector,

hence $S = \frac{(\omega L)^2}{R_a} = \frac{250\,000}{9 \times 3{\cdot}8} = 7\,300\ \Omega$

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Measuring Instruments for Wireless Circuits.

By C. H. Stephenson. **[R201**

Showing how, by the use of switches, one instrument may be made to do the work of several.

THE use of measuring instruments in wireless circuits gives the experimenter much useful and interesting information. Unfortunately, so far as anode circuits are concerned, the necessary apparatus is somewhat expensive, and this often prevents the purchase of a milliammeter and high tension voltmeter or, at any rate, limits the equipment to either one or the other. The following notes describe a means whereby a high tension voltmeter of suitable type may be made to serve the purpose of a milliammeter, and details are given of simple switching gear, so that the instrument may be permanently connected in an experimental circuit without risk of damage.

It is a basic fact that all measuring instruments in general use, with the exception of the electrostatic type, are current operated; that is to say, their readings are dependent on the strength of the current flowing through them. A voltmeter does not, in fact, directly indicate pressure. The displacement of the needle is an indication of the current passing through the instrument, which, in accordance with Ohm's Law, is proportional to the difference of potential or pressure between its terminals. The resistance of a voltmeter is made high so as to keep the passing current down to a minimum.

In the anode circuit of the receiver we wish to measure voltages of 100 to 200 and currents of 3 to 15 mA. In order to use a single instrument for these two purposes we require one which, when used as a voltmeter, passes about 15 mA at full scale reading, whilst its resistance must not be so high as to produce any serious drop of voltage when inserted in series with the anode circuit. Fortunately, such an instrument is readily available at a reasonable price in the Weston Model 301 voltmeter.

The writer uses one reading from 0 to 100 volts. It is provided with an external series resistance, and if the instrument alone, *i.e.*, without the series resistance, be connected in the circuit, it gives full scale reading when current of approximately 15 m.a. is passing. The resistance of the instrument alone is certainly quite negligible compared with that

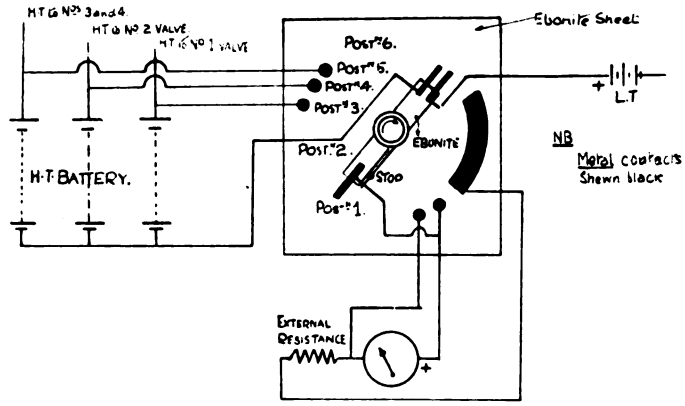

Fig. 1.

of the rest of the anode circuit, so no material drop of potential due to its use occurs.

It should be noted that the current is not exactly 15 m.a. for full scale reading, but it is so nearly so as to be sufficiently accurate for the purpose in view, and if greater accuracy be required an exact calibration is easily made by means of another accurate milliammeter or by a single accurate resistance of suitable valve and dry cell or accumulator of known voltage. It is also interesting to note that a similar model Weston voltmeter reading 0·5 volts gave full scale readings at almost exactly 15 m.a. There would seem to be a standard sensitivity for the movements of these voltmeters, the scaling being determined by the value of the series resistance.

After having proved the suitability of the instrument, it was found desirable to construct switch gear so as to permit a rapid change over of connection, bearing in mind the importance of making certain

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that the meter, without its series resistance, could not accidentally be connected across the H.T. supply.

The writer's experimental receiver consists of four valves so arranged that the detector may be used alone or in combination with one H.F. and one or two L.F. The H.T. supply is derived from three separate batteries, the two L.F. valves being fed from a common battery. It was necessary, therefore, to arrange matters so that the voltage on any valve plate and the current through any or all of the plate circuits could be read. The switch adopted is shown diagrammatically in Fig. 1, which includes the circuit connections. The following positions and readings were obtained :—

Switch Position.	*Reading.*
1	H.T. OFF.
2	H.T. ON.
3	H.T. voltage on valve 1
4	" " " 2
5	" " " 3 & 4
6	Total H.T. current.

As regards position 5 it will be clear that the H.T. current of any one valve may easily be arrived at. Suppose, for example, we require to know the current through valve 3 when valves 2 and 3 are in use, we should proceed as follows: Switch on to position 5; note current. Turn out filament 3 and switch receiver connections so that valve 2 only is operating. Note new current. The difference between the two currents is that taken by valve 3.

The arrangement may, of course, be used for obtaining the characteristic curves of valves of various types.

It has already been mentioned that the 0—5 voltmeter Weston type 301 in the writer's possession gives almost the same scale reading as does the 0—100 voltmeter when used. Probably the most generally useful single instrument is a voltmeter of this kind, and not until one is used across the filament terminals can it be appreciated how very inaccurate is the optical adjustment of filament temperature. It would not be difficult to arrange similar gear so as to connect a meter of this type across the filaments of any valves, or to put it in circuit as a milliammeter. If a suitable external resistance were made, the meter could be used as an H.T. voltmeter in addition so that a single instrument would very well serve three purposes.

As regards the actual design of the switch which the writer made, this is not advanced as being by any means the most suitable. It was made from parts available at the time, few tools being used, and, in practice, works quite well. The usefulness could have been extended had provision been made for reading the transmitting valve plate current and voltage. An extra series resistance would be necessary to extend the voltage reading to 300, or more.

Note.—The H.T. voltmeter should not be left switched in circuit, as the current passing through it will exceed that taken by the plate circuit and the life of the H.T. battery will be seriously reduced. This applies only when the meter is used for measuring the H.T. voltage.

WIRELESS WAVES AND PIGEONS.

A wireless experimenter at Paterna, near Valencia, Spain, recently made some observations on the apparent effect of wireless waves on the locational powers of carrier pigeons. During a transmission he released several of his pigeons, who circled over the station. He noticed that each time a pigeon passed over the aerial it faltered in its flight and, until it had staggered out of the electrified area, showed absolutely no recognition of the location of the house. Immediately it passed out of the charged area it resumed its flight to the pigeon cote. The effect was the same whatever the wave-length, although at less than 100W radiation the effect was less noticeable and the pigeons were quickly able to pick up their location.

AN ULTRA-SENSITIVE ELECTROMETER.

Monsieur C. Gutton (Professor of the Faculty of Nancy) and M. Laville have just presented to the Academy of Science, Paris, a new ultra-sensitive electrometer, which holds promise of great utility in the measurement of high frequency and small electric impulses. Using a 5mm. wide aluminium band suspended from a quartz "thread" 3mm. long, the inventors have an instrument which is easily portable (the mobile part weighing only 15 milligrams) and highly sensitive. The variation of a spot of light thrown on a scale at six feet is 100mm. for a volt; in fact, it may be said that the sensitivity of the electrometer is about 1/100 of a volt, irrespective of what difference of frequencies are measured.

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Some Experiments with Aerial and Earth Systems for Reception. [R321 : R326

By R. L. Smith Rose, Ph.D., M.Sc., A.M.I.E.E. and F. M. Colebrook, B.Sc. (Lond.), D.I.C., A.C.G.I.

The following paper, contributed by two experts having the resources of the N.P.L. at their disposal for their researches, clears up several doubtful points and gives some information particularly valuable to the ordinary licencee.

THE following is a description of some measurements carried out at the National Physical Laboratory, Teddington, with a view to determining the most efficient aerial and earthing systems for short wave reception, with particular reference to the use of an earth-screen for reception.

At the present time, the terms "counterpoise," "balancing capacity" and "earth-screen" appear to be used as if they were synonymous, whereas there is, in fact, a very definite distinction between the first two and the last. It will therefore be as well briefly to review the development of the technique of earthing systems in general with the object of emphasising the modern conception of the term "earth-screen."

Part I.—The Development of Earth-screens for Transmission.

The earliest type of oscillator with which Hertz first demonstrated the existence of electro-magnetic waves consisted of two metallic plates in the same plane, connected by a rod in which there was a small gap, each half of the rod terminating at the gap with a spark ball. All the experimenters who worked on the subject after Hertz used a similar form of oscillator (with its axis either vertical or horizontal) at both the receiving and the transmitting ends. This use of the simple form of Hertzian oscillator continued until Marconi discovered that by earthing one side of the spark gap, and retaining the other half of the oscillator as a vertical wire with a capacity plate or a network at the top, the distance to which signals could be transmitted was very much greater than had been obtained with the double plate oscillator. The explanation of the action of this earthed aerial system was based on the assumption that the earth, being a moderately good, if not perfect, conductor, gave rise to an image of the aerial with its elevated capacity, which image virtually took the place of the other half of the oscillator. On this assumption, much calculation and discussion has taken place on the subject of radiation and the propagation of waves generally.

The next step in the progress of aerial-earth systems was the introduction of tuning or, as it was termed at the time, "syntonic telegraphy." At this point a claim was made by Lodge and Muirhead (about 1909)* that the use of a Hertzian oscillator in the form of "upper and lower capacity" areas possessed advantages over an earth connection in the matter of selectivity and range of communication. Owing to the difficulty of making measurements in connection with wireless telegraphy as then practised, the relative advantages of the two methods of arranging the transmitter were not fully appreciated.

With continued practice and experience in the operation of stations, it was realised that to obtain the maximum radiated energy it was necessary to keep as low as possible the ohmic resistance of the aerial-earth circuit. As the efficiency of the other parts of the transmitter improved, it began to be appreciated that the greater part of the energy loss was centred in the earth connection, and from this was deduced the fact that the earth's crust is not such a good conductor of electricity, particularly at high frequencies, as many had previously supposed. This was confirmed by the marked superiority of many ship transmitting sets

* Proc. Roy. Soc., 82, p. 227.

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over corresponding stations on land, the superiority being due to the low resistance earth connection obtainable between the hull of the ship and the sea water, which is a moderately good conductor.

The earliest method of obtaining an earth connection at a land station was to run a single cable from the set to a buried metal plate. This, however, resulted in a comparatively high current density in the earth surrounding the plate, with consequent large localised losses. To reduce these it became the practice to run a number of feeders radially to a ring of metal plates buried, where possible, to the depth of the permanent ground water. In certain exceptional cases of high-power transmitting stations in localities where the ground was known to be of poor conductivity, the ring of plates was omitted and the radial wires extended to form the original type of counterpoise. A somewhat similar method was adopted for certain military sets, where, on account of its portability and ease of erection, an earth mat of wire gauze was used, laid on or pegged down to the ground.

Until recently, however, these counterpoise arrangements were looked upon as merely providing a low resistance path for the aerial currents to flow to, or as forming a condenser of considerable capacity to earth through which the earth connection for the high-frequency currents was established.

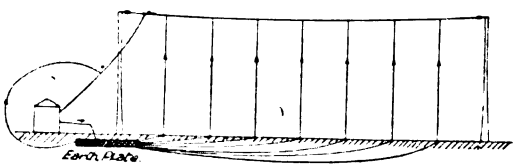

Fig. 1.

The dimensions of the counterpoise and its position relative to the aerial were not considered very important, and its size was usually cut down to the minimum from considerations of cost of land, etc.

That there were still large but avoidable losses taking place in such arrangements was first pointed out by T. L. Eckersley*, to whom the modern conception of the earth-screen is due. In the paper referred to he gave a theoretical analysis of the losses inherent in an aerial-earth transmitting system. He showed that the earth was the seat of ordinary ohmic resistance loss, eddy current loss, and dielectric loss, and that all of these could be minimised by the use of a properly designed earth-screen, the function of which is not only the provision of a low resistance path for the feet of the lines of force, but also the screening of the earth from the concentrated electric fields which would otherwise give rise to eddy current and dielectric losses. The basic principles can be simply explained by the aid of the three diagrams, Fig. 1, Fig. 2 and Fig. 3, which illustrate the directions of flow of the oscillatory currents in the aerial circuit. In Fig. 1 an inverted L-shaped aerial is shown connected to a buried earth-plate. It will be seen that the currents passing to the earth-plate have to flow through considerable portions of the earth material to various points under the aerial, whence the circuit is completed by capacity currents from the aerial wires to the earth's surface. In Fig. 2 the buried earth plate is shown replaced by a counterpoise network, situated on the side of the transmitter opposite to the aerial. It will be appreciated that although a large part of the earth-plate resistance is reduced by the distribution of the current over a larger area of copper, there are still considerable losses due to the return currents flowing through the earth. This, therefore, is an unfavourable position for the network. In Fig. 3 is shown the network in its most favourable position, *i.e.*, immediately under the aerial. With sufficient overlap provided on the screen beyond the horizontal projection of the aerial, all the lines of force due to currents in the aerial circuit are located in the air space between the aerial and the screen, and the dielectric losses previously taking place in the earth are thus avoided. Furthermore, if the currents are suitably distributed in the screen network, the eddy current losses which formerly occurred in the earth (due to the downward radiation from the horizontal part of the aerial) are largely if not entirely prevented by a similar radiation, opposite in phase, from the wires of the earth-screen.

In the paper by Eckersley referred to above, the theoretical analysis was confirmed by experiments carried out with small aerials. The results indicate very clearly

* T. L. Eckersley. "An Investigation of Transmitting Aerial Resistances," *Journal I.E.E.*, 1922, Vol. 60, pp. 581-594.

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the principles to be followed in the design of large transmitting aerials and earth-screens. For the benefit of those experimenters who are interested in transmission on a small scale, these underlying principles may be broadly described in the following brief résumé.

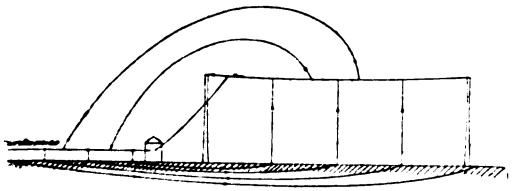

Fig. 2.

The screen is composed of a number of wires parallel to the direction of the aerial and supported in a horizontal plane symmetrically beneath the aerial. If space permits, the earth screen should overlap in every direction beyond the horizontal projection of the aerial for a distance at least equal to the height of the aerial above the screen. This means that for a flat-topped aerial of length 60 feet, total spread 10 feet, and mean height 40 feet, the dimensions of the earth-screen should be at least 140 feet by 90 feet. This may seem rather excessive to many owners of transmitting aerials, but the experimental results show quite clearly that a loss of span of the screen cannot be compensated by an increase in the number of wires.

The spacing of the wires running the length of the screen, and hence the number of wires, is chiefly dependent on the height of the screen above the ground, and a good working rule appears to be that the distance between the wires should be less than three times the height of the screen above the ground. To arrive at the best height of the screen above the ground a compromise must be made between various factors. If the ground beneath the screen is not required for any other purpose, the height may be reduced to about 3 feet (assuming that the vegetation can be kept down to a negligible height). For a screen of the dimensions given above, therefore, ten or twelve wires spaced 8 feet apart and 3 feet above the ground would be very suitable. More wires may be interspaced between these if desired, but even if the number of wires were increased up to 91, at 1 foot apart, the consequent additional reduction of resistance would be relatively small.

In many cases, however, it is not possible, for economic or other reasons, to monopolise all the ground under the earth-screen, and it will then be necessary to raise the screen to a height of 7 or 8 feet. The only objections to this are that the difficulty and cost of erection of the screen are thereby increased, and that the actual, and hence the effective, height of the aerial is reduced, since this is calculated from the level of the screen and not from that of the ground. If in the case above cited the height of the aerial is assumed to be 40 feet above the screen, which is 8 feet above the ground, a suitable arrangement would be six wires equally spaced at 18 feet apart. In considering the spacing of the wires, it should be remembered that such objects as iron and wooden fences and brick walls may be regarded as the ground and therefore as the seat of possible losses, and the screen wires should therefore be kept well away from such objects. The whole of the screen should be very well insulated, and, for the reason just given, the number of supporting posts should be reduced to a minimum. Unless they are absolutely necessary, no cross wires should be used in the screen, and the distant ends of the screen wires may be left free as in the case of aerials. In considering the leading-in arrangements of the screen, it is to be noted that in general the current passing from the transmitter to the screen will be somewhat greater than that passing to the aerial, so that careful arrange-

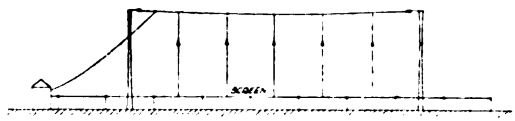

Fig. 3

ment of the feeder wires is necessary in *both* cases. The lead-in insulators are preferably situated at the centre of a glass or ebonite panel mounted in the wall of the building.

To illustrate the effect of the substitution of a screen designed on the above lines for a buried earth connection of the usual type, the case of the Clifden high-power station may be quoted. The total resistance of the aerial circuit was here reduced to one-sixth of its former value by the installation of a screen. This means that either 2·44 times

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the original aerial current can be obtained for the same input power, or that the same aerial current can be obtained with one-sixth of the input power formerly required. To those who wish to inquire more fully into the subject, the writers would recommend reference to Eckersley's original paper, and the discussion thereon.

In concluding this section of the paper, it should be mentioned that although the earth-screen gives the most complete solution of the problem of the reduction of the losses in the aerial circuit, the screens necessary for large transmitting systems (and the ground occupied by them) are so extensive and so costly that quite frequently a more economical—even though less efficient—solution has to be obtained. The most general solution at the present time is some sort of combination of the earth-screen with the multiple earth system originally devised by Alexanderson* and used at Rocky Point. The reader interested in further details of these arrangements may be referred to the original paper* and the later contributions of Meissner† and Bouvier.‡ The last-mentioned writer in particular discusses the whole question of earth connections in some detail, and describes the arrangements which were adopted at the high-power station at Sainte Assise, where the resistance of the aerial was reduced from 1·9 ohms with a buried earth connection, to 0·54 ohms, with a consequent increase of radiation efficiency of from 10% to 35%.

Part II.—Measurements on the use of an Earth-screen in Reception.

In connection with certain investigations which had to be carried out at the National Physical Laboratory on wave-lengths in the neighbourhood of 300 metres, it was decided to try whether the use of an earth-screen would afford any improvement in reception comparable with that obtained by the same means in the case of transmission.

It should be pointed out that there is no *a priori* justification for assuming that there will necessarily be any such improvement, since the conditions which obtain in the two operations are fundamentally different. In the first place it is only in certain cases, namely those in which there is no local source of energy associated with the reception process, as in crystal reception for instance, that the resistance of the aerial circuit plays a very important part. Again, the distribution of the electric fields involved will be very different in the two cases of transmission and reception. In the former case the field will be that due to a concentrated electromotive-force acting at one point in the aerial circuit. In the latter case there is, properly speaking, no electromotive-force in the aerial circuit at all, but instead a distributed potential gradient due to the line integration of a more or less uniform vertical electric field with respect to which the induced potential gradient is of the nature of a back E.M.F. of mutual induction. The fields in the two cases will differ both in distribution and, in general, very greatly in intensity, the received field being very small indeed compared with that usually associated with the transmitting aerial. However, the resistance losses will be essentially of the same kind, and some diminution of them can reasonably be anticipated, as the result of using an earth screen, though this diminution is not likely to be so striking as in the case of transmission.

At the outset of the measurements, certain factors were fixed as definite limitations, these being, first, the erection of any aerial which could be accommodated between two masts 30 feet high and about 80 feet apart; second, the use of a piece of ground 100 feet long by 30 feet wide quite free from any obstacles, but bounded on one side and end by an iron fence and on the other side by a wooden hut. A place was chosen in the hut near one of the masts, where the receiver could be erected and the measurements carried out. At this point there was also convenient access to both water and gas mains, and as these passed immediately underground for an uninterrupted length of about 100 yards they were representative of the usual type of such earth connections as employed for reception purposes. To complete the selection of earth connections available, a large sheet of tinned iron, about

* E. F. W. Alexanderson. *Proc. Inst. Radio Engrs.* 1920, Vol. 8, p. 279.

† A. Meissner. "The Earthing Resistance." *Year Book Wireless Telegraphy and Telephony*, 1922, pp. 1,235-44.

‡ P. Bouvier. "Multiple Earth Antennæ," *Radio Elec.*, 1922, Vol. III., pp. 456-466, 523-530.

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4 feet by 3 feet, was buried at a depth of about 3 feet immediately under the aerial and near the receiver. Two heavy stranded copper feeders were brought from this plate to a lead-in connection. Similar well insulated lead-in arrangements were provided for the aerial and the earth-screen. The aerial was maintained fixed in the form of two wires of 3/19 enamelled copper about 70 feet long, stretched between the tops of the masts, with a vertical down lead brought to within 6 feet of the ground and then carried horizontally to the lead-in insulator. In this, as in all the measurements the aerial was strained at the necessary points by insulated guys so as to keep its position fixed, thus avoiding any erratic changes of observed signal strength.

The actual measurement circuit employed is illustrated schematically in Fig. 4. The tuning arrangement is seen to consist of a variable condenser in series with a fixed inductance of suitable magnitude, followed by another small inductance across which is connected the rectifying unit. Between the latter inductance and earth is included a variable resistance box specially constructed for use at high frequencies.

The rectifying unit consists of a dull-emitter valve, in the anode circuit of which is connected a sensitive reflecting galvanometer. The normal anode current of the valve is balanced out of the galvanometer circuit by means of the potentiometer shown in the diagram. The grid circuit of the valve is the ordinary grid-condenser and resistance arrangement. The sensitivity is such that for a tenth of a volt applied between the grid and filament terminals a galvanometer deflection of about 1 metre is obtained. The calibration showed that for voltages up to about ·1 the galvanometer deflection was fairly accurately proportional to the square of the voltage. In the measurements, therefore the square root of the galvanometer deflection was taken as a measure of the radio-frequency potential difference due to the received current flowing through the fixed small inductance, and, since all the measurements were taken at a single constant frequency, that of the broadcast transmission from 2LO, this potential difference is itself a measure of the received aerial current. The actual magnitudes of the aerial currents were not determined, since only relative magnitudes were required for the purpose of the experiments.

In addition to the comparison of the aerial currents obtained with the various earthing arrangements, the total apparent resistance of the aerial circuit was also measured in each case. This was done by observing the changes of aerial current produced by the addition of known resistances. The method of calculating the total resistance of the aerial circuit from these observations may perhaps be new to some readers.

Since the circuit is tuned to resonance, we have, for an assumed E.M.F. E, an aerial circuit resistance R_0, and an added resistance R.

$$i = \frac{E}{R_0 + R_1}$$

i.e.,

$$\frac{1}{i} = \frac{R_0}{E} + \frac{R_1}{E}$$

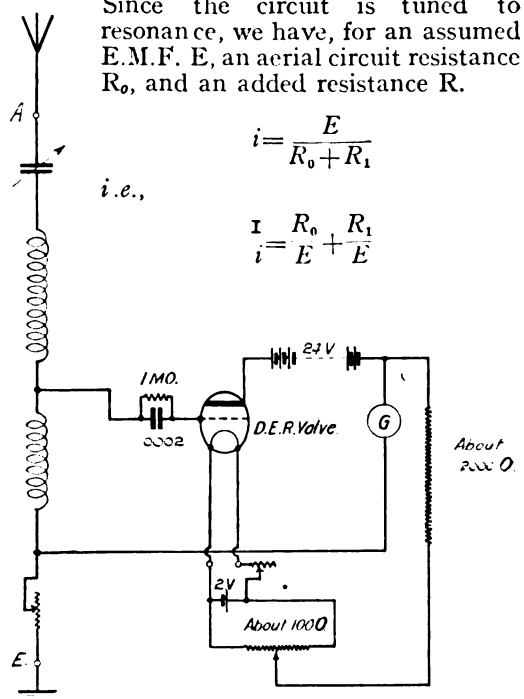

Fig. 4.

Thus if $1/i$ be plotted against R, the result should be a straight line. This line when produced backwards will cut the resistance axis at a point $-R_1$ such that

$$\frac{1}{i} = 0 = \frac{R_0}{E} - \frac{R_1}{E}$$

i.e.,

$$R_1 = R_0$$

It is interesting to note that this process is really the graphical determination of the negative resistance which must be inserted in the aerial circuit in order to make the aerial current infinite.

The constant part of the aerial circuit resistance which is due to the tuning circuit

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plus the small load effect of the rectifying unit can be determined by disconnecting the tuning circuit from the aerial, short-circuiting it upon itself, and then measuring its resistance in same manner as described above, using a local oscillator of the same frequency as the source of E.M.F.

In the actual measurements fairly good straight lines were obtained in the resistance determinations, the reciprocal of the square root of the galvanometer deflections being plotted against the added resistance. The above method of calculation has an advantage over the ordinary in that it shows up at once any errors of observation, and enables an accurate mean value to be obtained for all the observations.

Another quantity determined in each case was the reactance required to tune the aerial to the given frequency, *i.e.*, the total reactance of the tuning circuit between the aerial and earth terminals. All that is required for this is a knowledge of the inductance and the self-capacity of each of the two coils and the magnitude of the variable series tuning capacity. At a frequency $\omega/2\pi$ the reactance of a coil of inductance L and self-capacity C_0 will be:

$$X=\frac{\omega L}{1-\omega^2 LC_0}$$

If X_1 and X_2 be the reactances of the two coils calculated in this way, and if C be the series tuning capacity, then the reactance of the tuning circuit will be:

$$X=X_1+X_2-\frac{1}{\omega C}$$

(The values of L and C_0 for the two coils were found by plotting the square of the wave-length against the added capacity in the usual way.)

In order that a variety of earth screen arrangements could be tested, two triatic wires were erected across each end of the rectangular ground space, these wires being about thirty feet long, a hundred feet apart, and about three feet above the ground. (The aerial had previously been erected symmetrically over the ground space covered by the screen.) From these supporting wires any number of parallel screen wires could be hung, each separately insulated at the ends, and readily movable or detachable. In every case connection to the screen wires was made by means of a transverse wire about fifteen feet from the receiving end.

For the first set of measurements a screen of eleven No. 20 bare copper wires was erected, the space between them being about three feet. Readings were taken for the whole screen and compared with the corresponding readings obtained with various alternative earth connections. The screen wires were then removed and disconnected one at a time (the outer wire being removed from each side alternately), and the readings repeated. The results of this set of measurements are recorded in curves of Fig. 5 and

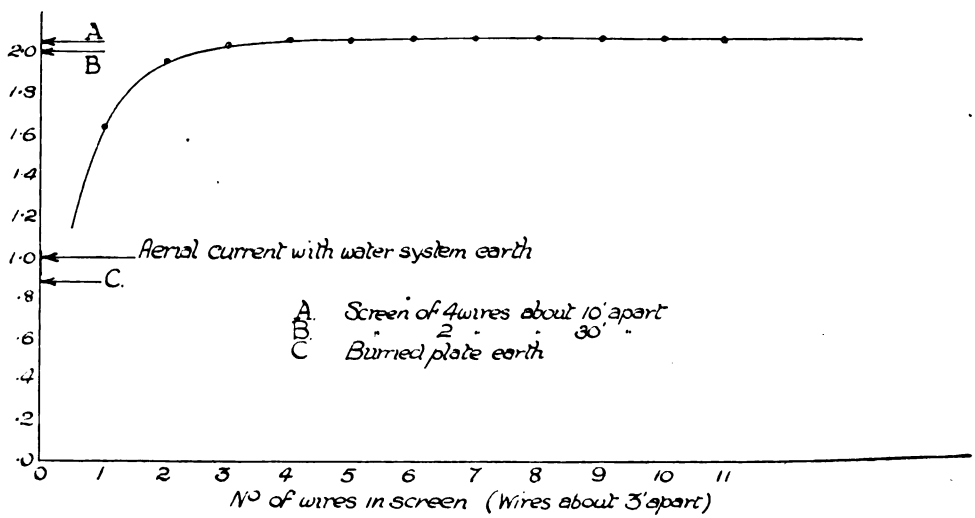

Fig. 5.

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Fig. 6. The conclusions to be drawn are as follows :—

1. With the screen the received current is approximately twice, and the aerial resistance just under a half the corresponding quantities when the water system is used as the earth connection.

the screen will be somewhat less than the capacity of the aerial to the earth. It will be noticed that as the number of screen wires increases, the tuning reactance decreases, approaching that required for the water system earth.

Since in many practical cases a screen of

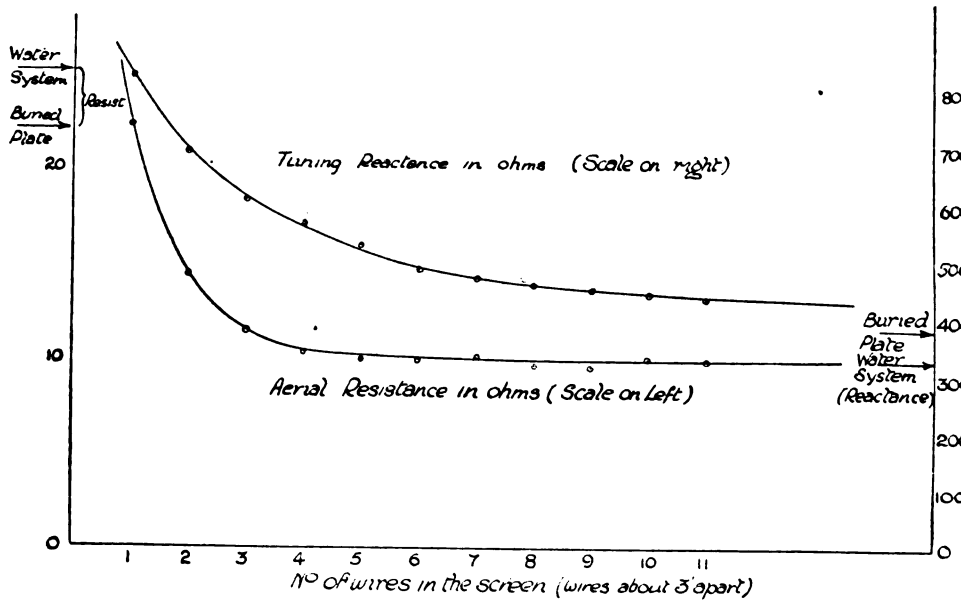

Fig. 6.

2. This result can be obtained by using a screen of three or four wires, and practically nothing is to be gained by increasing the number of wires beyond this point.

3. Earthing to the water system gives a slightly greater received current and a slightly lower aerial resistance than earthing to the buried plate. Earthing to the gas main was, in this particular case, very ineffective. This must not be taken as a general conclusion, since it was probably due to high resistance joints in the system. This result, however, emphasises the fact that earth connection to a gas system, apart from the disapproval of the gas and insurance companies, is always liable to this trouble, and that the water system is therefore preferable.

4. The tuning reactance required when using the screen is greater than that when using the water system or buried plate as earth connection. This is what one might anticipate, since the capacity of the aerial to

even as few as three wires arranged as described above will be impracticable, some additional measurements were made with a view to finding a more convenient disposition of the screen wires. First, four wires were distributed equally over the whole space, *i.e.*, about ten feet apart, and second, the two inner wires were removed, leaving a screen of only two wires running parallel to the aerial along the edges of the thirty foot space available. In each case the height of the wires was about three feet, as in the first series of measurements. The results are shown in the following table.

Screen.	Aerial resist.	Tuning react.	Ratio.
4 wires, 10 ft. apart	10 ohms	548 ohms	2·05
2 wires, 30 ft. apart	13·5 ohms	680 ohms	2·00

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(The figures given under the heading "ratio" indicate the ratio of the received current to that obtained with earth connection to the water system.)

It will be seen that two wires running down the edges of the available space form a screen which is only slightly inferior to the eleven-wire screen covering the whole space. The two-wire screen has the considerable practical advantage that it leaves unobstructed the whole of the space under the aerial, and thus brings the use of a screen in many cases in the sphere of practical politics. For instance, where an aerial is erected more or less centrally above the longest dimension of a garden, two well-insulated wires running parallel with it down the extreme sides of the garden will form an efficient earth screen.

A further measurement was made to decide whether the size of the wire used for the screen was a factor of any importance. For the two wires of No. 20 gauge used in the last measurement, two other wires of 3/19 aerial wire was substituted. It was found that there was no appreciable difference in the results obtained.

Finally, the effect of using the earth screen and the water-system earth together was observed. It was found that if the water system was directly connected to the screen the tuning reactance was about the same as that for the water-system earth only but that the received current was considerably less than that obtained with the water-system earth. This result is curious, and not easily explained. The difference in the tuning reactance required for the screen and the water-system earth might certainly account for the two not working well together when directly connected, but it is difficult to see why the maximum received current when the two are connected should be associated with the same tuning reactance as for the water-system earth alone, this maximum being considerably less than that given by the water-system earth alone.

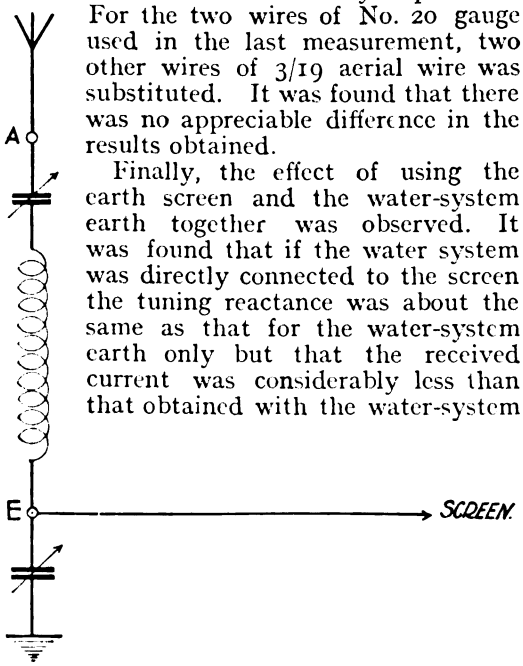

Fig. 7.

The difference between the tuning reactances associated with the two systems suggested that when the two are combined together some separate tuning arrangement should be used. Since, of the two, the water-system earth required the smaller reactance the use of an additional series condenser between the earth and the screen, as shown in Fig. 7, seemed the most simple method of obtaining the necessary compensation. For the first measurement this condenser was adjusted until the combination tuned with the same setting of the main tuning condenser as with the earth screen alone. This arrangement gave a received current only slightly greater than that obtained with the water-system earth alone. However, it was found that by a simultaneous variation of the main tuning condenser and the additional tuning condenser in series with the earth lead it was possible to find an arrangement which gave a greater received current than that obtained with either separately. The results are exhibited in the following table :—

Arrangement.	Tuning reactance.	Recd. current.
Water system earth ..	336 ohms	1
Screen of 4 wires, 10 ft. apart	548 ohms	2·05
Screen and earth directly connected	338 ohms	·65
Earth connected to screen through 800$\mu\mu$F ..	542 ohms	1·19
Earth connected to screen through 300$\mu\mu$F ..	497 ohms	2·32

It appears, therefore, that if an earth screen and an ordinary earth connection are used together, it is essential that the earth screen lead and the earth lead should be tuned separately. Under the usual conditions of broadcast reception, this will require a separate tuning condenser in series with the earth lead. Alternatively, it is probable that a small variable inductance in series with the earth-screen lead would be equally effective.

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Part III.—Experiments with various aerial arrangements.

The experiments already described showed conclusively that in all cases where aerial resistance is a matter of importance the use of an earth screen for reception will afford a very great improvement over any of the more usual alternative earth connections.

Attention was now devoted to the other half of the problem, *i.e.*, the most suitable design of aerial within the limits already specified, and subject to the post-office regulations relating to small aerials for broadcast reception.

distribution in terms of the constants of the aerial remains a very difficult problem, since we have to deal not only with a distributed inductance and a distributed capacity, but also with a distributed E.M.F. The question of re-radiation will also complicate the complete discussion.

However, certain conclusions can be reached from general principles. For instance, the received current at the base of an aerial will increase with the height of the aerial, and, for a given height, will also increase up to a definite limit with the increase of the top capacity. The object of the following measurements was to deter-

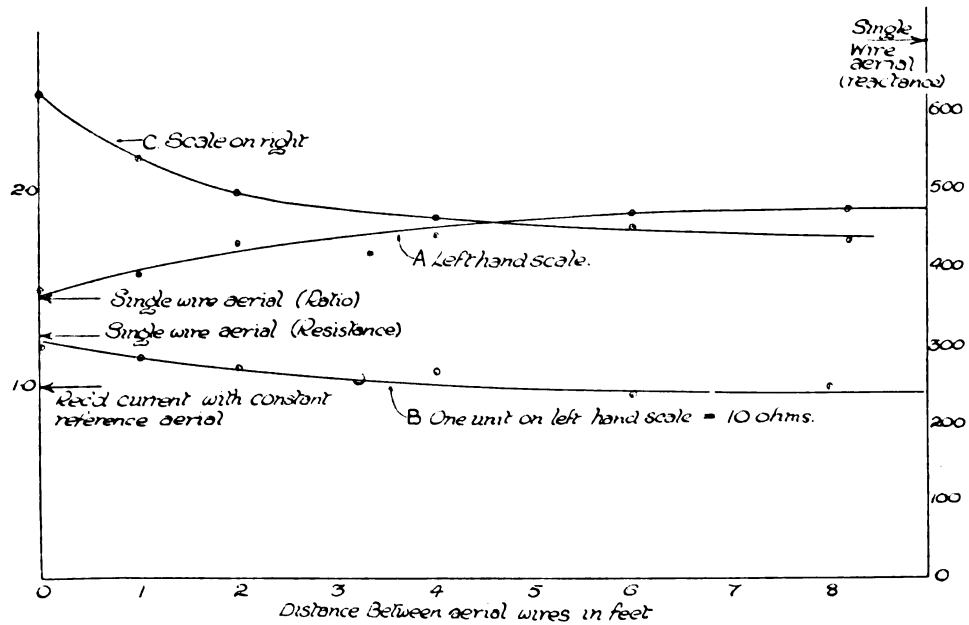

Fig. 8. *Effect of distance between wires. A, signal strength ratio; B, aerial resistance; C, tuning reactance required.*

Before describing the experimental work carried out on this subject it will be well to point out that the theoretical analysis of aerial reception is at present conspicuously incomplete—probably because of the inherent complexity of the subject. Information is lacking, for instance, on the matter of the effect of a receiving aerial on the shape and distribution of the electric field in its immediate vicinity. Moreover, even on the simplest assumption of a uniform vertical electric field, the determination of the current

mine relative importance of the above factors in the case of aerials used for broadcast reception.

The methods of measurement employed were the same as those already described in connection with the previous part of the paper. Throughout the whole of the measurements with various aerial forms the earthing system used was a screen of eleven wires about three feet apart and about three feet above the ground. This was done in order to reduce as low as possible the part

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of the aerial resistance associated with the earthing system, and so give greater prominence to resistance changes associated with variation of aerial form. In order to eliminate the effect of possible variations of the electric field from the source of the observed transmissions (*i.e.*, from 2LO), the received current was in every case compared with that given by a single wire aerial erected in the neighbourhood of the experimental aerial, this constant single wire aerial being used as a fixed standard of reference. The figures given for aerial current are therefore expressed in terms of the received current obtained with this reference aerial as unity.

amount. To complete this series of measurements a three and a four-wire aerial were erected, each occupying the full eight-foot spreader space. The results are shown in the following table.

Aerial.	Aerial. resist.	Tuning react.	Recd. current.
4 wires, 2 ft. 8 in. apart ..	11 ohms	315 ohms	1·78
3 wires, 4 ft. apart ..	10·5 ohms	365 ohms	1·75

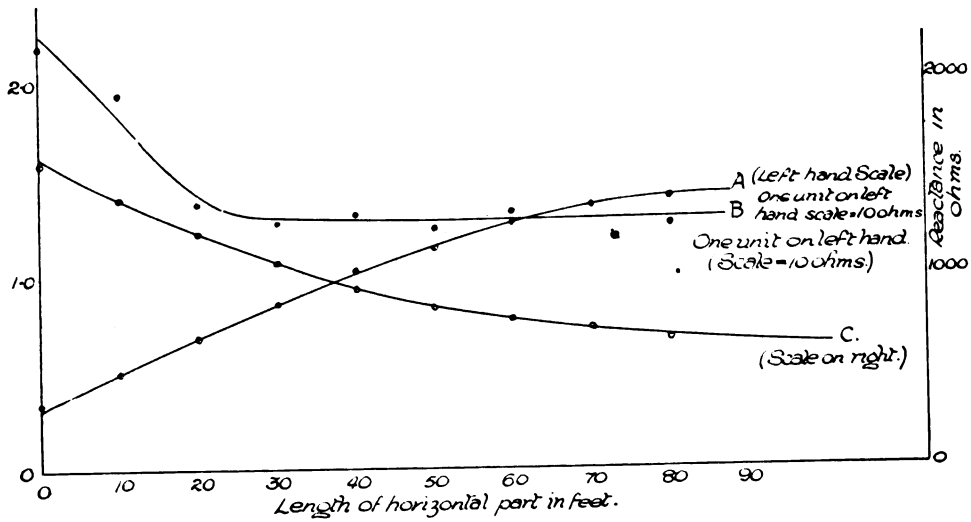

Fig. 9. *Effect of varying length of Top. A, signal strength ratio; B, aerial resistance; C, tuning reactance required.*

For the first set of measurements the aerial was in the form of two wires of 3/19 enamelled copper about 25 feet above the screen and about 75 feet long. The distance between these wires was decreased from 8 feet to zero and, finally, a single wire was substituted for the two adjacent wires. The results are shown in Fig. 8. It will be seen that if two wires are used they should be at least 6 feet apart, and preferably 8 feet. The most noticeable feature of the results is the comparatively small increase of received current obtained by using two top wires instead of one, the increase being only about 23 per cent. with a corresponding decrease in resistance of about the same

It will be seen on comparison with Fig. 8 that nothing is to be gained by increasing the number of wires in this way.

The next series of measurements was made with a single wire aerial of constant height, the horizontal part being about 25 feet above the earth screen. The length of the horizontal part was varied from zero to 80 feet. The results are shown in Fig. 9. As the length of the horizontal part is increased from zero to about 40 feet the received current increases according to a straight line law, the tuning reactance decreasing in a similar manner. Beyond this point the rates of change of these quantities decrease somewhat. It appears

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that little is to be gained by increasing the length of the horizontal part beyond about 80 feet. This indicates that up to about 40 feet of horizontal length the effective height increases uniformly with the length of the horizontal part, and that beyond about 80 feet of horizontal length the increase of horizontal length does not greatly increase the effective height.

For the last series of measurements a single wire aerial of constant total length was used (about 90 feet), and the height of the horizontal part above the earth screen was varied from 7½ feet to 25 feet. The results are shown in Fig. 10. Up to a height of about 20 feet the received current increases uniformly and is proportional to the height. Beyond this point it still increases, but not so rapidly. The comparison of these results with those of the preceding set indicates that there will probably be an optimum height for a given total length of aerial wire, and that this height is greater than thirty feet. The aerial resistance is seen to increase somewhat with the height, as might be anticipated.

It is hoped that later on there may be an opportunity of extending the scope of some of the above measurements by increasing the maximum height of the masts. From the above experiments, however, certain definite conclusions can be drawn. Of these the chief is that actual height and top capacity are of comparable importance. From the results of the last two sets of measurements it would seem probable that the most favourable distribution of a given total length of 100 feet of aerial wire would be about 40 or 50 feet of vertical height, the remainder being horizontal. A little can be gained by duplicating the horizontal part (*i.e.*, two wires in parallel) but not more than about a 20 per cent. increase in received current.

In conclusion it might be well to point out that while the advantages associated with the use of an earth-screen are chiefly important in the case of direct crystal reception, the best design of aerial within any given limitations is important both in crystal and in valve reception, since in each case it is desirable that as large as possible an E.M.F. shall be available in the aerial circuit. The main distinction between the two cases is that with valve reception a low aerial resistance is not so essential, since the proper use of reaction permits of independent control of this factor.

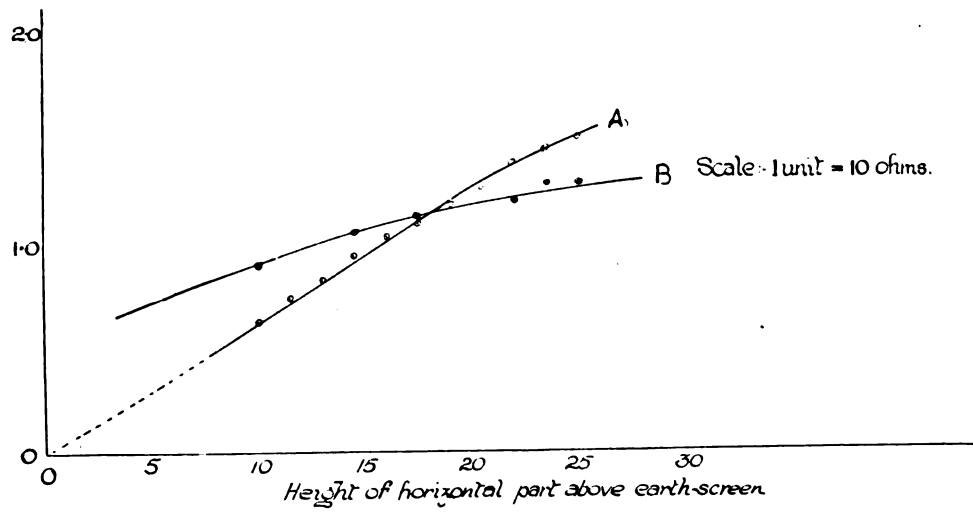

Fig. 10. *Effect of varying height. A, signal strength ratio. B, aerial resistance.*

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The Theory of the Lead Accumulator.

By N. A. de Bruyne. **[R800**

Student Member of the Faraday Society; Author of "Electrolytic Rectifiers."

IN the majority of practical books and papers on the action of the lead cell, the theory is dismissed in a few lines dealing with the fundamental cell reaction— $Pb+PbO_2+2H_2SO_4=2PbSO_4+2H_2O$. There is a great deal to be learnt, however, about the action of the cell by looking at it from the point of view of energy, or thermodynamics. We will begin by seeing how the E.M.F. of the cell can be calculated from the fundamental cell reaction.

Calculation of the E.M.F. of the Cell.

All chemical actions are accompanied by a rise or fall of temperature. The particular chemical action which goes on in an accumulator, if carried out in a beaker, gives rise to 120 860 calories of heat, if we use certain specified quantities of the reacting substances. When the reaction takes place in an accumulator the energy does not appear as heat, but as electrical energy. An accumulator is an apparatus for turning chemical energy into electrical energy; in the ordinary way, chemical energy gets transformed into heat energy.

We may express the production of heat by the fundamental reaction in the following equation :—

$$Pb+PbO_2+2H_2SO_4$$
$$=2PbSO_4+2H_2O+120\,860 \text{ (calories of heat).}$$

The above equation is merely a chemical way of saying that when 207 grams of lead, 239 grams of lead peroxide and 196 grams of sulphuric acid combine together to form 606 grams of lead sulphate and 36 grams of water, then 120 860 calories of heat are evolved. Now Joule showed that 1 calorie is equivalent to 4·2 watts per second; the cell reaction therefore gives $120\,860\times4{\cdot}2$ watt-seconds of electrical energy when it takes place in an accumulator. By Faraday's law, however, $2\times96\,540$ Coulombs of electricity will pass through the cell during the action between the above quantities of lead, lead peroxide and sulphuric acid. Thus, $4{\cdot}2\times120\,860$ watt-seconds and $2\times96\,540$ Coulombs of electricity are produced by the cell reaction. Remembering that watts equal volts multiplied by ampères and that Coulombs are ampères multiplied by seconds, we obtain the E.M.F. of the cell by dividing the number of watt-seconds by the number of Coulombs, thus :—

$$\frac{4{\cdot}2\times120\,860}{2\times96\,540} = 2{\cdot}6 \text{ volts approx.}$$

By actual experiment it has been found that the voltage of an accumulator using strong acid is 2·6 volts, correct to the nearest tenth of a volt.

Effect of Dilute Acid.

If we use dilute acid (that is to say, a mixture of pure acid and water) the amount of heat evolved will be less than in the case considered above, because of the heat of solution of the acid. Everyone knows that when strong acid is dissolved in water the solution heats appreciably; conversely if we could get the acid out of the water again the solution would be cooled. When we allow lead, lead peroxide and dilute sulphuric acid to react together, the chemical action takes the pure acid away from the water, forming lead sulphate; thus, part of the energy of the reaction is used up in giving back the heat of solution to the water. Therefore, instead of getting the full 120 860 calories, we only get part of this heat, the E.M.F. of a cell decreasing with increase in dilution of electrolyte. Therefore, to obtain a high voltage we must use a strong solution of sulphuric acid; unfortunately, if we increase the strength of the acid much beyond a specific gravity of 1·215 sulphation takes place very easily.

Effect of the Heating and Cooling of the Cell when in use.

We saw above that we could calculate the E.M.F. of a cell correct to a tenth of a volt by using the heat of the reaction. If we make our calculations to a hundredth of a

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volt, however, we find that they no longer agree with experimental results; that is to say, the theory outlined above only gives approximate results. The reason for this is that the cell cools on charge and heats on discharge. Now, since the cell cools on charge, it takes in heat from its surroundings, thus it will have a higher E.M.F. than that calculated from the heat of the reaction; and on the other hand, since it heats on discharge it will have a lower E.M.F. than that calculated from the heat of the reaction, because part of the electrical energy is being wasted as heat energy.

Gibbs, Helmholtz and Kelvin have shown how this heating and cooling may be taken into account in the calculation of the E.M.F. The accurate E.M.F. is given by the following expression, whose derivation is too long to be given here :—

$$E = \frac{Q}{46\,000} + T\frac{dE}{dT}$$

where Q = Quantity of heat in calories evolved by chemical action.

T = 273+Temp. in degrees Centigrade.

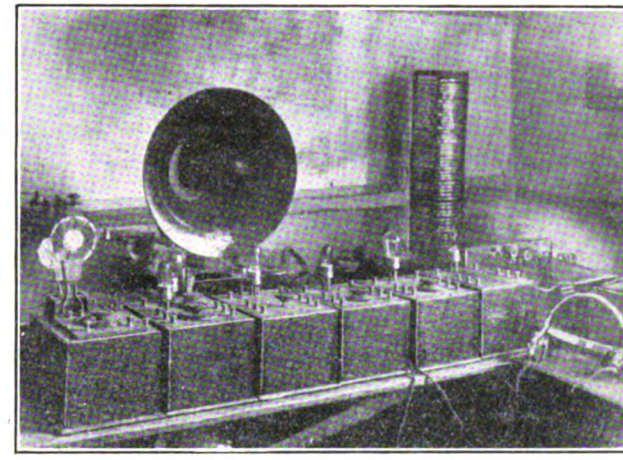
$\frac{dE}{dT}$ = Rate of variation of the E.M.F. per degree Centigrade.

E = E.M.F. in volts.

Therefore, if we can determine experimentally the numerical value of $\frac{dE}{dT}$, we shall be able accurately to calculate the E.M.F. This is not easy to do, since the term is very small; its value and sign also depend on the concentration of the acid used. For acid of density 1·156 Streintz has found $\frac{dE}{dT}$ = ·000 335; if we take the temperature as 17° C., the second term of the expression equals ·0971 volts. With acid of density 1.156 the heat of reaction is 88 800 calories; substituting these values in the equation, we find E=2·0275 volts. Actually, the value is 2·030 volts; thus, the agreement between theory and practice is good.

The Solution Pressure Hypothesis.

In the preceding paragraphs we have regarded the lead accumulator as a machine for turning chemical energy into electrical energy; and it has been shown how the E.M.F. can be calculated by the aid of this conception. We will now turn our attention to another way of looking at the action of the cell, and see how the E.M.F. can be calculated (theoretically, at any rate) by a new method. This new view of the working of the cell is given by Nernst's "Solution Pressure Theory."



AN AMATEUR STATION.

Our photograph shows the arrangement of Mr. A. Acland's set on which he has received 80 American C.W. stations. Amateur stations in New Zealand and the Argentine have also been logged. The Helix in the background consists of 96 turns of copper tape, and is used as an artificial aerial.

According to the Ionic theory, electrolytes are split up into ions, and electrolysis is a process which consists in attracting these ions to the respective electrodes. Thus, salt (sodium chloride, NaCl) when dissolved in water is split up into sodium ions which are positively charged, and chlorine ions which are negatively charged. When a current is passed through the solution, the sodium ions are attracted to the cathode, and the chlorine ions to the anode. Now, the chemical action that goes on in an accumulator is almost certainly a reaction between ions, not an action between compounds. For instance, the lead takes part

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in the action as lead ions ; that is to say, is the form of small positively charged particles in the solution.

Action at the Negative Electrode.

Thus, the lead electrode sends ions into solution. These positively charged lead ions leave the lead electrode with a negative charge, in accordance with the electron theory, provided that the accumulator is on open circuit. If the terminals of the cells are joined by a wire, then this negative charge on the lead electrode will be conducted away. The solution pressure theory, therefore, gives a vivid picture of the source of the E.M.F. of the cell. Since the lead electrode is negatively charged, it will attract a large number of the ions back to its surface, while, at the same time, it is continually sending ions into solution. In this manner, a state of equilibrium is reached between the lead ions and the lead electrode ; that is to say, the lead electrode does not go on sending ions into solution indefinitely.

This equilibrium is upset when the accumulator is connected to a circuit, and when a current flows more ions are sent into solution. By Faraday's law, the passage of 96 540 Coulombs through the cell will cause 103·5 grams of lead to go into solution as ions. We can think of the lead electrode as having a definite pressure which drives the ions into solution. When there is equilibrium (when the cell is on open circuit) this solution pressure of the lead electrode is balanced by the pressure of the ions round the electrode.

Call the solution pressure of the lead electrode p_1. Then the work done at the lead electrode when 96 540 Coulombs are discharged from the cell can be calculated by the following expression :—

$$W = RT \log_e \frac{p_1}{p_2}$$

where W = Work done.
R = A constant.
T = Absolute Temp. (That is 273+Temp. in degrees Centigrade.)
p_1 = Solution pressure of electrode.
p_2 = Concentration of lead ions in main body of electrolyte.

Knowing the work done at the electrode, we can easily calculate the E.M.F. due to the lead electrode in much the same way as we calculated the E.M.F. of the cell from the heat of the reaction. Putting in a numerical value for R, taking the temperature at 17° C., the expression for the E.M.F. due to the lead electrode becomes :—

$$E = \cdot 02\,88 \log_e \frac{p_1}{p_2}$$

Action at the Positive Electrode.

There are two theories respecting the nature of the ions which the lead peroxide plate sends into solution. They are known as Liebenow's and Le Blanc's theories ; without going into these theories or deciding between them we can say that the E.M.F. due to the positive electrode is given by the following expression :—

$$E = \cdot 02\,88 \log_e \frac{p_3}{p_4}$$

where p_3 = Solution pressure of lead peroxide plate.
p_4 = Concentration of anions, whatever those anions may be, in main body of electrolyte.

The E.M.F. of the whole cell will be due to the combined effects of the separate E.M.Fs. of the lead and lead peroxide electrodes.

The E.M.F. of the whole cell will therefore be :—

$$E = \cdot 02\,88 \log_e \frac{p_1 \times p_3}{p_2 \times p_4}$$

Deductions from the Solution Pressure Theory.

From the above expression for the E.M.F. of the cell we can draw a number of interesting conclusions. We see from the expression that if E is to be large p_1 and p_3 must be big, and that p_2 and p_4 must be small. Now we cannot alter the solution pressures of the lead electrode or the lead peroxide electrode, but we can alter the values of p_2 and p_4. For instance, if we use an electrolyte in which lead is very soluble, then p_2 will be large and the E.M.F. of the cell will be correspondingly small (since the term p_2 occurs in the denominator of the expression). In the same way if we use an electrolyte in which lead peroxide is very soluble, p_4 will also be large and the voltage of the accumulator will be reduced. Lead peroxide is comparatively soluble in caustic soda ; and we find that a lead cell with a caustic soda solution does have a very small E.M.F.

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The Effect of a Shunt Detector in Aerial Tuning. [R144

By F. M. Colebrook, B.Sc. (Lond.), D.I.C., A.C.G.I.

This note forms an interesting example of the application of the Author's article on Impedance Calculation in our last issue.

AERIAL tuning is a very difficult subject to handle mathematically. The fact that the aerial inductance, capacity and resistance, and also the E.M.F. induced in the aerial, are all distributed quantities makes the received current at the base of the aerial a complicated function of the aerial constants. Failing an exact analysis, however, the following more or less empirical presentation of the case will enable some useful deductions to be made with regard to the association of a crystal or other relatively low resistance shunt detector with an aerial tuning circuit.

Assuming that the aerial and earth terminals are fixed in position relative to the aerial and the earthing system, it will be found that in order to tune the aerial to any given frequency a certain definite reactance X_a must be introduced in some way between these terminals. Over the range of values likely to occur in practice this reactance X_a will be found to be independent of the magnitude of the resistance associated with it, provided the latter is kept constant during the tuning process, and also independent of the manner in which it is introduced, whether it be by variometer, series or parallel condenser tuning, or any combination of these. Again, it will be found on applying the usual method of inserting known resistances directly in series with the aerial and observing the consequent changes of aerial current, that the part of the aerial external to the aerial and earth terminals appears to have a definite resistance at any given frequency. Let us call this resistance R_a. Two cases now present themselves. If the detecting arrangement be one which consumes an inappreciable amount of power (a condition which can be realised by the right use of valve apparatus), then the best tuning circuit is the one which introduces the necessary reactance X_a with the minimum of resistance. If, on the other hand, the detecting arrangement is one which operates by the consumption of power, then the correct tuning arrangement is that which introduces the necessary reactance X_a, together with a power consuming term, *i.e.*, an effective resistance, of magnitude R_a. The condition is in fact analogous to any case in which power is taken from a source of E.M.F. having a certain internal resistance, the optimum condition in all such cases being that the load resistance is equal to the internal resistance. We see from the above that the ideal variable reactance-crystal detector combination is that which introduces into the aerial an effective impedance R_a+jX_a.

Tests with Standard Aerial.

It will be of practical interest to relate this to the standard P.O. aerial and the reception of broadcast transmission. The reactance required to tune a standard aerial to the transmission from 2LO, for instance, will vary somewhat with local conditions, such as the height of the horizontal part of the aerial, but it will generally lie between 400 and 600 ohms (positive). The effective resistance of the aerial is also a very variable factor, depending chiefly on the quality of the earth connection. Probable limits for this quantity are 10 ohms in favourable conditions to 80 or even 100 ohms in cases where the earth connection is of small area in dry soil.

It can now be shown, by means of the circle diagrams described in the author's recent article*, that the ideal tuning conditions specified above are very unlikely to be realised in the usual form of crystal

* E.W. & W.E. Dec., 1924, p. 140.

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receiving circuit, of which three common types are illustrated in Fig. 1, *a*, *b* and *c*. In cases *a* and *b*, the crystal and telephones are in shunt to the whole of the variable tuning reactance. These cases are therefore identical in type with that considered in the diagram of Fig. 11 of that article, the

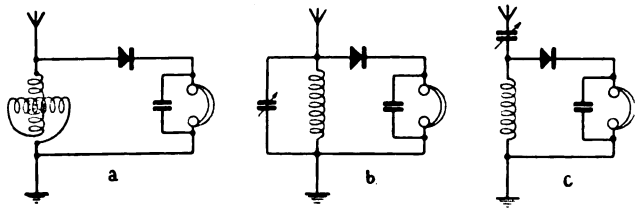

Fig. 1.

constant shunt resistance being that of the crystal. (It is here assumed that the effect of the wire resistance of the coil is relatively negligible.) The high frequency resistance of a crystal detector may be anything from 1 000 to 5 000 ohms, varying with the type and specimen of the crystal. The resistance of a telephone or other apparatus in series with the detector does not enter into the calculation, since any such apparatus should be short-circuited by a condenser for the high frequency component of the current in the detector circuit. To obtain some idea of the order of the load imposed on the aerial by a crystal receiving circuit of a usual type we can therefore take as representative values: X_a, 500 ohms; R_a, 50 ohms; shunt detector circuit, 2 000 ohms. The diagram corresponding to these values is shown in Fig. 2. The measured value of R_a, the effective resistance introduced into the aerial circuit, is seen to be about 140 ohms, more than two and a half times the desired value.

If the crystal resistance were lower, say, 1 000 ohms, the conditions would be even worse, for the effective resistance load would then be as high as 500 ohms. In such a case as this the point of maximum signal intensity would probably not be the real tuning point of the aerial, since the process of tuning would increase the effective resistance at a rate that more than balanced the decrease in reactance.

The series condenser case illustrated in Fig. 1*c* is likely to be even less efficient than the others unless a correspondingly high resistance crystal is used, for, whatever negative reactance, is introduced by the condenser has to be balanced by a correspondingly increased positive reactance introduced by the inductance. Thus, if the series condenser is about 1 000 $\mu\mu$F, giving a negative reactance of about 200 ohms at the frequency of the 2LO transmission, the effective reactance of the inductance-crystal circuit combination must be 700 ohms, in order to give a resultant effective reactance of 500 ohms between the aerial and earth terminals. The diagram shows that under these conditions a 2 000 ohm crystal would introduce a load of nearly 290 ohms into the aerial circuit.

This overloading of the aerial with resistance is undesirable for two reasons. Firstly, it is inefficient from an energy point of view, resulting in a lower signal intensity than could be obtained under the correct conditions; secondly, it gives rise to unnecessarily flat tuning, with a corresponding decrease in selectivity. It will be preferable, therefore, to use some type of circuit which permits of the control of the resistance load introduced into the aerial independently of

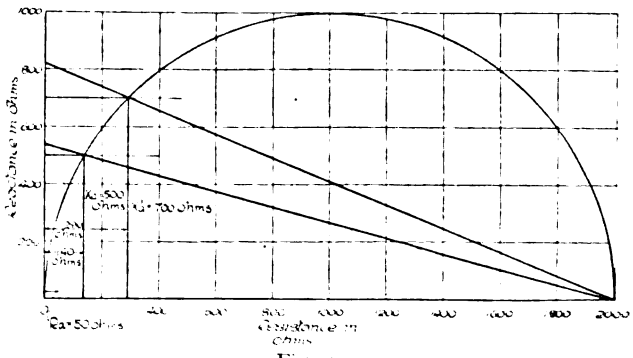

Fig. 2.

the tuning conditions and the crystal resistance.

A simple and effective means of obtaining this control is afforded by what was originally the general practice with crystal circuits, namely, to connect the detector circuit in parallel with a part only of the tuning

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reactance, the proportion of this part to the whole being variable.

It will be seen on reference to Fig. 11 in the article already mentioned, that the smaller the reactance associated with a given shunt resistance the less will be the effective resistance of the combination. With either of the circuits illustrated in Fig. 3, the amount of the reactance in parallel with the detector circuit can be varied independently of the variation of reactance necessary for tuning the aerial. Either of these circuits will, therefore, give control of the effective resistance introduced into the aerial by the detector circuit. Of the two circuits illustrated, the first is slightly the more efficient, but the second is considerably more convenient to manipulate.

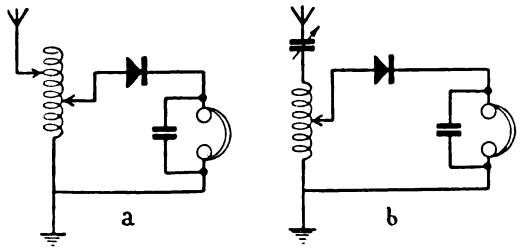

Fig. 3.

In either case the coil should be wound with bare wire of about No. 18 or 16 gauge, on some form of insulating frame which reduces as far as possible the proximity of solid dielectric to the wire. The turns should be not less than two or three wire diameters apart.

It may be of interest to describe some experiments carried out by the writer which furnish a qualitative confirmation of the theoretical discussion given above. It was shown in the article to which reference has already been made that, in the reception of modulated high frequency waves by means of a crystal detector, there will flow through the crystal a continuous current of magnitude proportional to the square of the high frequency E.M.F. acting across the detector. The energy consumed in the detector is also proportional to the square of this E.M.F. Thus, the continuous current through the crystal will serve as a measure of the energy being absorbed by it. At distances up to 15 miles or so from 2LO the continuous current through the crystal can be measured by means of a reflecting galvanometer of moderate sensitivity. A simple and convenient means of comparing different arrangements or of analysing the behaviour of any given circuit is to insert such a galvanometer in series with the telephones (both galvanometer and telephones being shunted by a condenser to provide a low impedance path for the high frequency components of the current). This was done by the writer for a number of different cases. In particular, the effect of varying the tapping point of the detector circuit was investigated for the case illustrated in Fig. 3*a*. The curves shown in Fig. 4 can be taken as typical of the results obtained. The coil consisted of about 20 turns of No. 16 copper wire, of about 10 inches diameter. The abscissæ indicate the number of turns included in the detector circuit, and the ordinates are the corresponding galvanometer deflections (proportional to the continuous current through the detector). It will be seen that, in the case of a galena crystal, the optimum condition was reached when only four turns of the coil were included in the detector circuit, the galvanometer deflection being then four times as large as it was when the whole coil was included in the detector circuit. It was noticed, moreover, that the tuning of the aerial became very much flatter as the number of turns included in the detector circuit increased.

The curve corresponding to the perikon detector differed from the former curve in a manner consistent with the fact that the

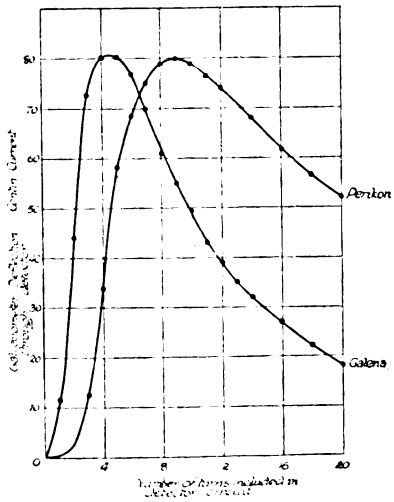

Fig. 4.

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resistance of a detector of this type is, usually, four or five times as large as that of a galena crystal, the differences being that a larger number of turns can be included in the detector circuit before the resistance thus introduced into the aerial exceeds the optimum value, and that the falling off beyond the optimum condition is less rapid than in the case of the lower resistance detector. (The curves must not be taken as indicative of the relative sensitivities of the two detectors, since the galvanometer sensitivity was in each case adjusted so as to give deflections of convenient magnitude.) It is clear that whatever type of detector is used its full sensitivity will not be obtained unless it is suitably connected to the circuit. It is desirable that a detector should have a low resistance. In this respect galena has the advantage over perikon, but, as will be seen in the curves of Fig. 4, this characteristic makes it all the more important that the correct load conditions should be realised. With a circuit of either of the types illustrated in Fig. 3, the optimum condition can easily be found by trial.

It should be pointed out that the measurements were made with a standard P.O. aerial of very low resistance. If the aerial and earthing system have a high resistance, the correct detector conditions will be much less critical, but the overall efficiency will be correspondingly reduced. On the other hand, the advantage of low aerial and earth resistance will be completely lost unless the load introduced by the detector circuit is controlled in some such manner as that indicated above.

A Great Swedish Station. [R611

MANY interesting features are attached to the Grimeton Station—the largest radio station in Sweden—which has been completed recently in spite of various difficulties.

Actually the system comprises two separate stations, one at Grimeton being used for transmission, the other at Kungsbacka being used solely for reception. Both stations are handled from a remote control centre at Göteborg.

The Kungsbacka station was completed last spring and, in a series of tests, gave very satisfactory results. The aerial is on a large scale and consists of 13 kilometres of copper wire supported by 90 posts. It is suspended between the station and the far side of a valley and has been specially erected with the object of being directional so far as New York is concerned.

The Grimeton transmission station, which is housed in a two-storey concrete building, is equipped with duplicate plant which can be operated separately or jointly. Each unit consists of an Alexanderson type of high-frequency generator having a capacity of 200 kW and a periodicity of 17 400.

It is expected that, in the normal course of working, only one unit will be employed and that the other will be held in reserve so that, in the event of a breakdown, there will be no serious interruption of the service.

The wave-length of 18 000 metres has been selected, not particularly as a matter of convenience, but because it is not commonly used by other European stations.

The power supplied to Grimeton will come from turbo-generators at Yngaredsfors and Trolhaettan. This will be supplied at a pressure of 40 000 volts and will be stepped down at the station to 2 000 volts for the transmission sets and 120 volts for the lighting circuits.

The height of the masts supporting the transmitting aerial varies from 110 to 130 metres according to the nature of the ground so that the aerial may be perfectly horizontal at a uniform distance of 110 metres above the ground level. The erection of the masts has proved quite an interesting engineering problem. Over 900 tons of timber and iron have been used in their construction and each mast has been built up *in situ*. Cross arms at the top of each mast carry the 12 wires of the aerial and the masts are spaced at intervals of 380 metres.

The earth system consists of a network containing 200 kilometres of 3 millimetre copper wire. It is 500 metres wide and is buried at a depth of 50 centimetres.

The total cost of the plant is estimated at 4,850,000 Swedish kroner, but it is believed that the outlay will be amply justified.

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The Perfect Set.

Part IV: L.F. Amplification: the Coupling. [R342·7

In continuation of our last article we have a few more points about valve handling, followed by a discussion of the three best-known types of coupling.

IN the last instalment of this series we began the consideration of L.F. amplification, and tried to show how one could ensure by a simple and systematic method that there should not be distortion in the valves themselves, whatever occurred elsewhere. There was not space to indicate how the requirements there laid down would react on the design of the set.

We will now tackle this point, for it can be covered in not too many words. First, we cannot ensure correct filament heat except by putting an instrument in circuit. In these days of bright, thoriated and oxide-coated filaments, it is becoming quite impracticable to judge by eye. The writer's method is to bring out a lead from between rheostat and filament of each valve to a separate socket (Clix), and plug the voltmeter into each as required; the other side of the meter is, of course, connected to the common filament return.

Second, unless we propose to use similar valves throughout, we must provide separate grid and anode battery tappings. For work up to room strength, it will hardly be necessary to have *more* than one power valve; and the author refuses to consider seriously any telephony set not using one for the last stage. So that one is very likely to have two types for L.F. work. In practice, one can often work off one value of *either* H.T. or G.B. (grid bias), for there is no serious objection to using extra H.T. on an ordinary valve, providing the output is kept reasonable by correct bias, and the anode voltage is not *too* high.

At this point, perhaps one may mention a practical point which, though hardly a matter of principle or theory, is of great assistance. If it can possibly be afforded, keep a milliammeter in the plate circuit of any broadcast set. The writer has one which originally cost about 30s., and reads 10mA for full deflection. It is placed in the common return to the H.T. battery. An accurate instrument is not necessary, though very nice to have. Its advantages are two. Any distortion *due to the valves* will show at once, for such distortion means a partial rectification of audio-frequency currents to D.C., and the pointer will swing. This ammeter is a more sensitive indicator than even a trained ear. Also, it is a valuable indicator in case of breakdown. If signals fail, but the ammeter shows its normal reading, we know at once that all plate, grid and filament circuits are intact, or, at any rate, continuous. We have only to look for coil and condenser shorts or a fallen aerial, or ring up the studio and tell them *they* have broken down.

The Coupling.

Now, still dealing with attempted distortionless telephony amplification, we come to the intervalve coupling. For L.F. work, there are just three familiar methods:—

(1) Resistance.
(2) Choke.
(3) Transformer.

It is in order to discuss shortly the relative merits of the three. Transformer coupling is generally considered to give high amplification, but to introduce distortion. There are, however, one or two transformers now available which give extremely little distortion when properly used; and there is another point to be considered. Most loud-speakers (and to a less extent, telephones) have a lower limit of frequency below which they do little, and it is of little use to make terrific efforts to get full amplification at such frequencies. If it were only a matter of a few per cent., one could find a coupling which would sufficiently emphasise the low tones to compensate. But we believe that in many cases the loudness of the loud-speaker at 50 cycles is only about one-tenth of that at 300 or 400, with the same input. In such a case, one must give up all attempts to reproduce, and can, with regret, sacrifice this part of the scale in the amplifier.

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The resistance-coupled amplifier is supposed to be quiet but distortionless. In practice, it may be louder than a transformer set if there is not proper grid bias in the latter (King Charles' head again!), and a resistance amplifier may distort, howl and perform every conceivable beastliness if not properly designed.

Lastly, the choke set is described as having the advantages of both and the disadvantages of neither (by its friends) and exactly the opposite (by its enemies). In practice, it has the advantage of requiring less H.T.; but the design of the chokes (though not so difficult as the design of a transformer) is by no means so simple as sometimes thought.

Resistance Amplification.

Dealing with the resistance amplifier, we need say comparatively little, for the subject was admirably covered by Mr. F. M. Colebrook in an earlier issue.*

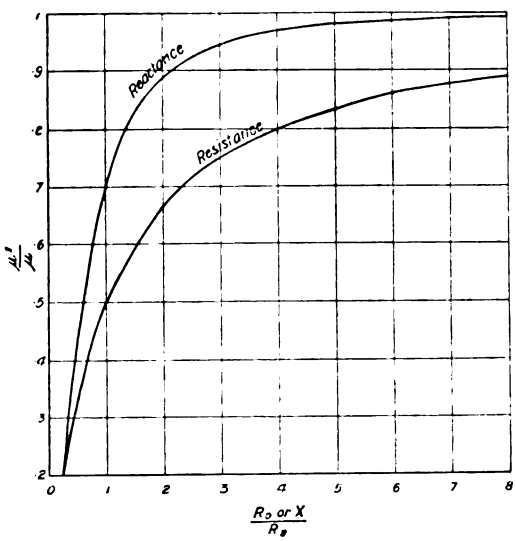

Fig. 1.

In this article Mr. Colebrook puts forward certain criticisms of transformer amplifiers which in our own opinion are unduly severe as regards sets using some of the latest designs. But as far as the resistance coupling itself is concerned there is not much to add to his article. Grid-leaks of low value (250 000Ω) are recommended, and grid condensers of not less than ·05μF: it is stated that larger condensers are not necessary, but attention is called to the very great importance of really high insulation in these condensers. Mr. Colebrook had not at the time of writing that article found satisfactory anode resistances of compact type, and was using wire-wound coils of 47 S.W.G. Eureka (constructional details were given). It is, of course, necessary to keep the self-capacity low. Personally, the writer, though not a great user of resistance amplifiers, has found a proprietary anode resistance containing a sticky liquid (nature unknown) quite reasonably satisfactory.

It is most important to realise that grid bias (again!) is even more important than ever in these amplifiers. The "time-period" of the condensers and leaks used is of the order of $\frac{1}{50}$ second; i.e., if the condenser ever gets charged up it will take about $\frac{1}{20}$ second to get nearly discharged, and during this period amplification will be upset. So it must never get any "permanent" charge, i.e., there must never be any grid current.

One should remember that in resistance amplifiers it is the *ratio* of outside anode resistance to valve anode impedance that matters. Hence care should be taken to use valves of impedance suited to the resistances in hand, etc. Since all the amplification in each stage has to be done by the valve, one is tempted to use valves of high μ; but it is well to remember that in the ordinary way such valves have also a high R_a, and hence need high resistances. An exception, of course, is the new power type especially designed for this work, with a μ of 20 and R_a of only 20 000Ω. It is also worth remembering that modern power valves of the B4, D.E.5, or D.F.A. types, with μ of 7 or so, have values of R_a down to 5 000Ω or less, and hence can be used with resistances of 20 000Ω. If they are used with the usual 60 000Ω or the like, it will be necessary to provide very high voltages—something like 1 000 volts. In designing anode resistances for power valves, do not forget that they may have to carry say 15mA: 47 S.W.G. wire is barely heavy enough for real safety.

Choke Coupling.

The essential point about the choke amplifier is that it is meant to behave like the resistance type. The choke is intended

* F. M. Colebrook. "Further Notes on Resistance-Capacity Amplification." E.W. & W.E., Sept. 1924, p. 712 *et seq.*

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to offer to *all* audio-frequency currents an impedance nearly equal to the resistance in the other type, while having a comparatively low actual D.C. resistance We say "nearly" equal because (as may easily be proved mathematically) we can get the same amplification with rather less impedance in a choke amplifier than resistance in a resistance amplifier. Fig. 1, for example, shows the results to be expected from each. The horizontal axis shows different ratios of external resistance or reactance to the anode impedance of the valve; the vertical axis shows the ratio of μ', the actual amplification theoretically obtainable for the stage, to μ, the amplification factor of the valve; in other words the approximte efficiency of the coupling. You will notice at once that the choke coupling appears much more efficient.

But there are complications. For the choke coupling to be efficient, the reactance must be large—not so large as the resistance, but still large. But the reactance is not a constant. It is 6·28 times the frequency multiplied by the inductance in henries. So that the inductance must be so large as to give almost the full effect *at the lowest frequency we wish to reproduce.* Suppose we say that an efficiency of ·9 at 50 cycles will suffice. Then if the anode impedance of the valve is 20 000Ω, we must have a choke of about 128 henries.

This means a winding of about the same character as the secondary of an intervalve transformer. If it is to be confined in a reasonable space it will behave in a somewhat similar way to a 1 to 1 transformer; that is, it will not be a pure inductance. It will have an ohmic resistance of 1 000—2 000Ω, and an additional effective resistance representing losses in the core. It will also have a self-capacity, which may be comparatively large. In fact, it will have (to a lesser degree, because it resembles a 1 to 1 ratio) all the peculiarities of transformers. It will *not* be free from distortion unless the skill of a transformer designer is put into it; but, even if badly designed, it will not distort so much as a bad transformer.

No detailed design can possibly be given in the space available, but the following is a basis for experiment. Choose the type of transformer you like best (or dislike least). Build a similar core of Stalloy. Wind on 10 000 turns, in four or five sections with a clear space of 1 mm. to 1/16 in. between them, of the largest wire that will go in, the wire to be enamelled and D.S.C. if available, otherwise S.S.C. Fig. 2 shows the sort of thing, about natural size.

Apart from the choke, and the fact that normal H.T. is used instead of extra high values, the design of such a set is essentially that of a resistance amplifier.

Transformer Sets.

As regards the transformer-coupled amplifier, the problem resolves itself into the design of the transformer in itself, on the

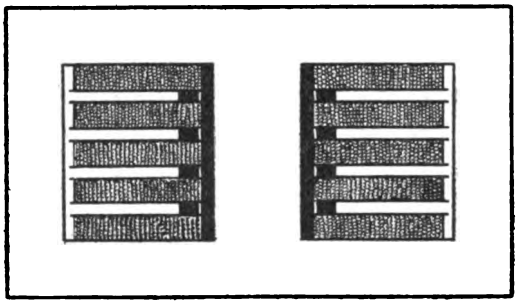

Fig. 2.

one hand, and in using a transformer suited to the valve, on the other. The question of transformer design is an extremely difficult one, but will not directly concern our readers, who will almost certainly buy their transformers. In fact, about the only item left to the user is the choice of ratio. This is simple in theory. To a first approximation, the turns ratio should be the square root of the ratio of secondary load to primary outside impedance. For example, if the load on the secondary were one megohm and the primary impedance (i.e., the anode impedance of the preceding valve) were 20 000Ω, the ratio of these would be 50, and the turns ratio should be about 7. But there are enormous difficulties. The load put on the transformer by the grid circuit of the next valve depends not only on the valve and its adjustments, but also on the output load on that valve. Further, the transformer's own self-capacity may put a heavier load on it than the valve circuit itself.

The net result of all this is that the user can only be guided by rough approximate considerations founded on practical experience. A good empirical rule to find a

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suitable ratio is : find the output impedance of the previous valve. Divide 250 000 by it. Take the square root of the result.

Thus with the average modern British dull-emitter, having an impedance of about 16 000O, we get 250 000 ÷ 16 000 about 16, so the turns ratio should be about 4. The next main point about a transformer is to see that it has plenty of iron in the core. This is, of course, only one of many points, but it is one that can usually be seen. The best transformer we know has a core about 1 in. square. There are few as large as this, but—unless you have definite proof of good performance—avoid transformers with mean cores.

Readers who are not advanced in their knowledge will perhaps find the long and masterly article by D. W. Dye (E. W. & W. E., Sept., Oct., Nov.), rather too much for them. But, leaving aside his argument, they would derive immense benefit by studying the conclusions, on p. 80 of the Nov. issue. Also a short non-technical abstract of the article will be found in the Sept. issue, p. 687.

In practice, the comparative strength of high and low tones, as reproduced by a transformer-coupled amplifier, may be changed easily by loading the transformer, either primary or secondary, with resistances or condensers or both.

A load on the secondary will produce the same result as a *different* load on the primary, according to the following rule : if r is the turns ratio, a condenser C on the secondary produces the same effect as a condenser r^2C on the primary ; a resistance R on the primary equals a resistance r^2R on the secondary (note the opposite effects). Hence one uses a large resistance and small condenser on the secondary. It will usually be found that a resistance below 1 megohm or a condenser above .001 will produce either loss of strength or serious muffling ; any reasonably good transformer will give its best with less loading than this.

If there are several stages, it is as a rule not necessary to load each stage individually. Obviously the desirable thing is to use such good transformers that none at all is needed.

Different Forms of Distortion.

Perhaps this is the place to make the general point that there are at least two totally distinct types of distortion (they may, of course, occur together,, which we will call, for lack of better terms, "wave form distortion" and "amplitude distortion." The former consists in changing the form of the audio-frequency wave, by the introduction of harmonics, or the partial suppression of those rightly present. The latter consists in a different degree of amplification for different frequencies, as for example inferior amplification of bass notes—a very common fault. Strictly speaking, these two forms are not entirely distinct, for since a harmonic is a note of higher frequency than the fundamental, "amplitude distortion" will either increase it or diminish it, and so cause "wave-form distortion." But the broad distinction is a useful one, for they sound different, and are usually caused in different ways.

Amplitude distortion makes the general tone sound high or low, or in some cases causes a very clear loss of extreme notes, such as the deep notes of an organ or the top ones of a piccolo. But the notes produced may be perfectly sweet and clear.

Wave-form distortion, if, as is most common, it is enhancing the harmonics, makes nearly every note have a shrill sound—a sort of rasp, as it were. If the reverse is happening, it gives a muffled, booming effect.

As to causes, in the vast majority of cases the valves cause wave-form distortion and the couplings amplitude distortion. The valves cause wave-form distortion (excess of harmonics) if there are any of the troubles described last month, and the couplings may cause it if there is too little iron in transformer cores (excess of harmonics), or if excessive loading condensers are used (harmonics lost). The couplings will almost always cause some amplitude distortion, though perhaps only at the extreme end of the scale. It is *possible*, using a resistance coupling and skill, to get practically even amplification from 50 to 10 000 cycles. It is not unduly difficult, using transformers and skill, to get a *sufficiently* even result from 200 to 10 000.

To sum up : *For practical domestic work* there is not a great deal between the three types ; one can be guided by the practical needs of the case.

No type is fool-proof. The resistance type, however, does not place one entirely in the hands of the transformer maker.

As a personal opinion of the writer, the matters in *last* month's article are more important than those in *this* month's !

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The Efficiency of the Counterpoise.

By M. C. Ellison. **[R326**

Our contributor brings some evidence tending to show that the counterpoise is not so efficient as earth.

EDITORIAL NOTE.

We publish this article with pleasure, in the hope that it may lead to discussion. The views are our contributor's, and he expressly states that he realises that the tests are not conclusive. Perhaps some readers may be able to show a fallacy.

THE counterpoise has always been a sort of talisman to the transmitting amateur, as by erecting one he can nearly always greatly increase his radiation over that obtainable with the ordinary earth and consequently he imagines that his signals are carrying a correspondingly greater distance. I say "imagines" because I consider, after careful tests, that the reverse is the case. In order to carry out these tests a portable high frequency voltage measuring set was made up, consisting of a simple oscillating circuit supplying a Moullin valve voltmeter properly calibrated.

In order effectively to compare the efficiency of a transmitter using a counterpoise with one using an earth, the field strength must be measured. This was done by measuring the voltage induced in a coil tuned to the transmitted wave. The measuring set was accordingly set up first in the same room as the transmitter, which was started up, first with the counterpoise and afterwards with the earth, great care being taken to keep the radiation and the wave-length, which was 185 metres, constant the whole time. With a radiation of half an ampère the following readings were obtained: with the counterpoise 1·3 volts, with the earth 2·55 volts. The apparatus was then taken into the garden and set up about 50 yards from the aerial, a small aerial and an earth pin being used in order to get larger readings.

With a radiation of half an ampère and the transmitter connected to the counterpoise a voltage of ·3 volt was obtained, whereas with the transmitter connected to earth the reading was ·7 volt.

As the radiation that could be obtained with a given power was greater with the counterpoise than with the earth, a test was made keeping the power constant, the radiation with the counterpoise being ·65 amp and with the earth ·58 amp. The voltages obtained were ·8 with the counterpoise and 1·35 with the earth.

It is, of course, realised that these tests are not by any means conclusive, as readings ought to be taken at long ranges and under every conceivable condition before the matter can be regarded as settled.

It would be very interesting to have the opinions of other transmitting amateurs as to the value of the counterpoise. One prominent amateur, who, by the way, was successful in the Transatlantic tests, on being shown the above figures, remarked, firstly, that he doubted them, and, secondly, that whereas using a counterpoise he could radiate three ampères, using an earth the radiation fell to one ampère.

Be this as it may, the author has certainly found that a counterpoise is a disadvantage both in transmission and reception, the only advantage apparent being the reduction of the fundamental wave-length of the aerial, which is a distinct help when working on very short waves.

COUNTERPOISE EXPERIMENTS.

TABLE OF RESULTS.

Position of voltmeter.	Radiation.	Voltage obtained. Counterpoise.	Voltage obtained. Earth.	
In transmitting room	·5	1·3	2·55	
50 yds. from aerial	·5	·3	·7	
,, ,, ,,	·65	·8	—	Constant power.
,, ,, ,,	·58	—	1·35	Constant power.

Wave-length 185 metres.

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The Graphical Analysis of Composite Impedances.

Supplementary Note.

ON page 143 of our last issue, in the article by Mr. F. M. Colebrook, there will be found, at the top of col. 2, the statement that "from the geometry of similar figures it follows that

$$OC = R_0$$
$$CD = X_0,"$$

in the figure given there and reproduced here.

It appears that some readers have not realised the reasons for this, so we give the proof herewith.

In justice to Mr. Colebrook, we should like to make it clear that the proof was in his original MS., but was omitted by us to save space.

In the circuit of Fig. 9 of the article (also reproduced here), call Z the true impedance between P and Q. Then, R_0 and X_0 being the equivalent resistance and reactance,

$$Z = R_0 + jX_0 \quad .. \quad .. \quad (9)$$

But from the actual circuit,

$$\frac{1}{Z} = \frac{1}{S} + \frac{1}{jX} = \frac{1}{S} - \frac{j}{X} \quad .. \quad (10)$$

But from (9),

$$\frac{1}{Z} = \frac{1}{R_0 + jX_0} \quad .. \quad (14)$$

Multiplying top and bottom by $R_0 - jX_0$, and remembering that the amplitude of Z, which we will call Z, is given by

$$Z^2 = R_0^2 + X_0^2 \quad .. \quad (15)$$

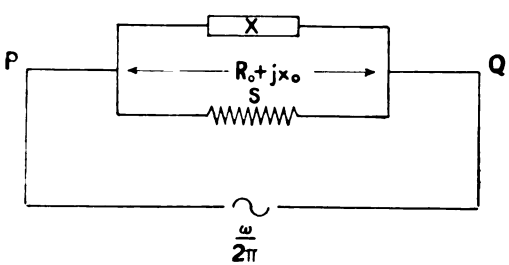

Fig. 9.

we have

$$\frac{1}{Z} = \frac{R_0 - jX_0}{R_0^2 + X_0^2} = \frac{R_0}{Z^2} - j\frac{X_0}{Z^2} \quad .. \quad (16)$$

From (16) and (10), we have

$$\frac{R_0}{Z^2} - j\frac{X_0}{Z^2} = \frac{1}{S} - \frac{j}{X} \quad .. \quad (17)$$

From the known properties of complex quantities, we thus have

$$\frac{R_0}{Z^2} = \frac{1}{S} \quad .. \quad .. \quad (18)$$

$$\frac{X_0}{Z^2} = \frac{1}{X} \quad .. \quad .. \quad (19)$$

or

$$\frac{S}{Z} = \frac{Z}{R_0} \quad (20)$$

$$\frac{X}{Z} = \frac{Z}{X_0} \quad (21)$$

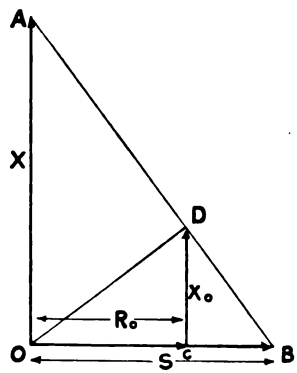

Fig. 10.

Now in Fig. 10, by similar triangles,

$$\frac{OB}{OD} = \frac{OD}{OC}, \text{ and } \frac{OA}{OD} = \frac{OD}{CD} \quad .. \quad (22)$$

hence

$$\frac{S}{OD} = \frac{OD}{OC} \quad .. \quad .. \quad (23)$$

$$\frac{X}{OD} = \frac{OD}{CD} \quad .. \quad .. \quad (24)$$

Comparing equations (20) and (21) with (23) and (24), we see that (20) and (21) are satisfied by

$$OD = Z \quad .. \quad .. \quad (25)$$
$$OC = R_0 \quad .. \quad .. \quad (26)$$
$$CD = X_0 \quad .. \quad .. \quad (27)$$

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Re-opening CKAC—Montreal

By E. H. Turle, A.M.I.E.E. **[R612**

THE re-opening of CKAC, with its new and enlarged transmitting plant, making it one of the largest broadcasting stations in the British Empire, was followed with interest by experimenters throughout the world, and already some remarkable reports of reception have been received.

The apparatus at the station embodies many recent improvements, and Captain P. P. Eckersley, of the British Broadcasting Co., who recently visited the station, expressed the opinion that, in view of the great difficulties that had to be overcome, a most gratifying result had been achieved.

Although the new apparatus at CKAC was manufactured by the Canadian Marconi Company, Montreal, it is interesting to note that all the fourteen 2 000-watt valves used are of English make. The arrangement includes one power amplifier, three oscillators, four modulators and six rectifiers.

A special feature of this station is that the energy, before going to the modulators, is subjected to three-phase double-wave rectification by means of six valves. The ordinary public lighting supply is thus used to operate the transmitter—eliminating any motor generator—and the particular form of rectification ensures absolute clarity and tone purity in the broadcasting.

Special care has been taken that no carrier-wave noise and no generator hum of any kind can cause distortion or interfere with the faithful reproduction of voice and music, whether transmitted direct from the elaborately-arranged studio of the great Canadian newspaper, *La Presse*—which both owns and controls the station—or brought in, through remote control, from various points.

Fig. 1 shows the Marconi rectifying unit which supplies 12 000 volts to the modulators and oscillators. These six rectifying valves are mounted on a separate panel and are operated by remote control, the unit being located two floors below the operating room.

Before the converted sound energy from the magnetic type microphones reaches the actual transmitting apparatus, it is treated to five stages of voltage amplification and also power amplification. After passing through this amplifying stage, it is passed into the transmitting power amplifiers, whence it is fed through modulators to the three oscillators and then radiated from the aerial. The aerial is suspended from towers erected on the roof of the *La Presse* Building.

The set operates on choke control, and is extremely simple to manage. In spite of its 14 valves, one operator only is required to keep the set functioning after it has been brought into action by the closing of a single switch.

The new studio has been most carefully designed and is considered acoustically perfect. An elaborate system of sliding

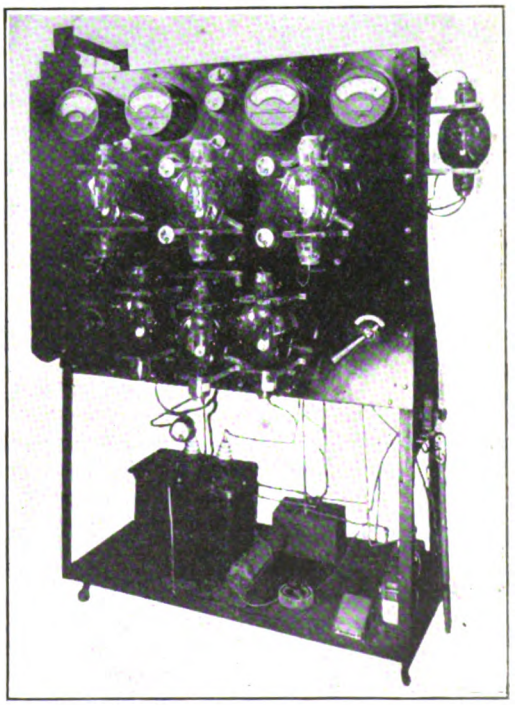

Fig. 1.
The three-phase, double-wave rectifier, which supplies 12 000 volts to the modulators and oscillators.

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curtains brings in echoes at will or deadens the studio to absolute silence when required.

Blue-lined plush curtains, Chinese reed furniture, and old ivory-finish make the studio combination. The microphone seen in the photograph (Fig. 2) is of the Marconi magnetic special type used exclusively by CKAC.

Blue, white and red lights keep the Director, Mr. Jacques N. Cartier, and also the announcers and operator in communication with each other at all times.

Although primarily intended to cater for some five millions of French-speaking people scattered throughout the various Provinces of the Dominion, several States of the Union, the island of St. Pierre Miquelon, the West Indies and the Guianas, with the new plant in use, there will be practically no limit to the distance which CKAC can reach. Consequently, it has of necessity become the only tri-lingual station in the world, and uses French, English and an international language — unfortunately, in spite of the ARRL decision as regards amateur work, Esperanto is not the one used.

Recently, with the courteous co-operation of the British Broadcasting Co., experimenters throughout Great Britain were invited to assist in a test reception, and among the large number of reports sent in to the writer the following may be mentioned :—

At Lelant, Cornwall, using a three-valve set, Mr. W. W. Bastain was able to follow the programme from 1.15 G.M.T. onwards, despite atmospherics, which everyone agrees were particularly bad. At Northampton Mr. S. R. Lenton, using two H.F., det. and one L.F., at 2.0 a.m. received the concert at loud-speaker strength. At Barmouth, Wales, Mr. E. G. Owen, using a two-valve reflex set, and at Bridgend Mr. David Thomas, using 1-v-1, were also successful.

Under favourable conditions, CKAC is also regularly heard in Alaska, Denmark, France, Italy, etc., and is now reported to have been heard in New Zealand and, it is said, even in India.

Fig. 2.
Part of the luxurious studio at CDKA.

A Well-Equipped Ship. [R610

IT is interesting to compare the wireless equipment of ships nowadays with the pre-war standard of one spark set with emergency gear. A case in point is R.M.S. *Aorangi*, now being built for the Union Steamship Co. of New Zealand, the equipment of which will comprise both spark and C.W. transmitters (the latter having a range of 2 000 miles), an automatic call device, direction finding instruments, and a wireless telephony set for ship to shore communication with a range of 50 miles. A special aerial is to be provided for broadcast reception, and in connection with this 17 loud-speakers are to be installed. Two motor lifeboats will be fitted with ¼kW spark sets having a range of from 50 to 60 miles.

Spark transmission will be handled by a 1½kW Polar synchronous set with a range of 800 miles and this will have an emergency stand-by gear. Other features include a special receiving set, employing the latest receiver and oscillator and a new note-tuned amplifier, which it is claimed is highly selective and immune from atmospheric disturbances, and covers all waves up to 20 000 metres. The whole of the apparatus is being supplied and fitted by the Radio Communication Co.

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The Rejector Circuit—its Theory and some Applications. [R140

By O. F. Brown, M.A., B.Sc.

REJECTOR circuits consisting of a coil in parallel with a variable condenser across which high frequency alternating potentials can be applied, have been used since the days of crystal reception; and the introduction of the three-electrode valve has still further extended their application. Nevertheless the explanation of their action as given in popular text books is often very inadequate. In the present article the theory of such circuits is considered both in the case when the resistance of the coil is neglected and in the case when this resistance, still assumed small, is taken into account. Some applications of such circuits in modern receiving apparatus are then described and explained.

Let us consider an alternating high frequency E.M.F. of maximum value E applied to the circuit of Fig. 1 consisting of a coil of self-induction L and a condenser of capacity C. Let the frequency of the applied E.M.F. be given by $n=\frac{\omega}{2\pi}$.

Assuming that the circuit LC has no resistance losses, then the maximum current in the coil is

$$I_L=\frac{E}{\omega L}$$

This current will lag behind the applied voltage by an angle of 90°.

The maximum value of the current in the condenser will be given by

$$I_C=\omega CE$$

and this current will be leading the applied voltage by an angle of 90°.

The two currents I_L and I_C are thus 180° out of phase and the current in the leads to the source of the alternating applied voltage is given by

$$I=I_L-I_C=\frac{E}{\omega L}-\omega CE.$$

If the circuit is tuned to the frequency of the applied E.M.F., then $\omega^2LC=1$ and therefore $I_L=I_C$, and current I is zero. The rejector circuit LC therefore acts to the applied E.M.F. as if it had an infinite impedance.

The application of the E.M.F. to the rejector circuit, since there are no ohmic losses, will result in an oscillation being built up in the circuit itself. The energy for this oscillation will be stored alternatively as magnetic energy round the coil and as electrostatic energy in the condenser. The maximum value of this large oscillating current will be, since $\omega^2LC = 1$.

$$I_L = I_C = \omega CE = E\sqrt{\frac{C}{L}}$$

If the rejector circuit is not tuned to the same frequency $\frac{\omega}{2\pi}$ as the applied E.M.F., but to some other frequency, the difference between I_L and I_C is no longer zero, and the rejector circuit will now allow a current I in the outside connections. It can easily be seen that the current through the condenser will be greater than that through the coil if the frequency of the applied E.M.F. is *greater* than that to which the rejector circuit is tuned, and conversely that the current through the condenser will be less than that through the coil if the frequency of the applied E.M.F. is *less* than that to which the rejector circuit is tuned.

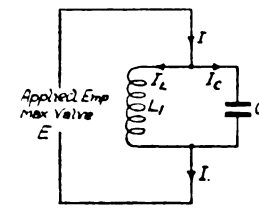

Fig. 1.

If the rejector circuit is tuned for a particular frequency, the values of the capacity of the condenser and the self-induction of the coil can be varied so long

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as their product LC retains its proper value. For a frequency of the applied E.M.F. not equal to that for which the rejector is tuned the difference between the currents ωCE and $\frac{E}{\omega L}$ will be larger, the greater the ratio $\frac{C}{L}$ and therefore the larger will be the current I passing through the circuit. Thus the greater the ratio $\frac{C}{L}$ the less is the impedance offered by the rejector to an E.M.F. of non-resonant frequency.

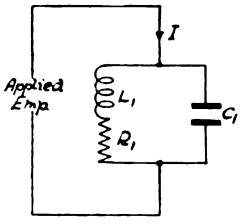

Fig. 2.

We have hitherto considered the rejector to be entirely without resistance losses. If, however, the coil has an ohmic resistance R the circuit can be represented as shown in Fig. 2. In this case the current I_L will equal $\frac{E}{\sqrt{R^2+\omega^2L^2}}$. This current will not now be lagging 90° behind E, but will lag by an angle ϕ given by $\phi=\frac{L\omega}{R}$. If it is assumed that the condenser possesses no resistance the current through it will, as before, be given by $I_C = \omega CE$, and it will lead the applied voltage by 90°. The magnitudes and phases of I_L and I_C can be represented by a vector diagram as shown in Fig. 3. It is seen from this diagram that current I_L can be resolved into two components: (1) $I_L \cos\phi$ in phase with the applied E.M.F., and (2) $I_L \sin\phi$ 180° out of phase with the condenser current. Sin ϕ and cos ϕ being given by

$$\text{Sin } \phi=\frac{L\omega}{\sqrt{R^2+\omega^2L^2}} \text{ and } \cos\phi=\frac{R}{\sqrt{R^2+\omega^2L^2}}$$

If now the rejector circuit is tuned to the frequency of the applied E.M.F. then the component $I_L \cos\phi$ represents the current flowing through the circuit from without, while the component $I_L \sin\phi$, which is opposed to the condenser current makes up the oscillating current *in* the rejector circuit itself.

The current in the outside circuit is thus given by $I = I_L \cos\phi$.

$$=\frac{E}{\sqrt{R^2+\omega^2L^2}} \cdot \frac{R}{\sqrt{R^2+\omega^2L^2}}$$

$$=E \cdot \frac{R}{\omega^2L^2} \text{ approximately, if R is small}$$

$$=E \cdot \frac{RC}{L} \text{ since } \omega^2LC=1.$$

Similarly $I_C \sin\phi = \frac{E}{\omega L}$ approximately.

Thus the circuit acts to the applied E.M.F. as if it were a non-inductive resistance of value $\frac{L}{RC}$ ohms.

The oscillating current as before is given by $E\sqrt{\frac{C}{L}}$

In cases where the frequency of the applied E.M.F. is not equal to the frequency for which the rejector is tuned, there will flow in the outside circuit the same current as found above in phase with the applied voltage, and in addition a current out of phase by 90° with the applied voltage and equal to the difference between I_C and $I_L \sin\phi$.

Rejector circuits have been and still are largely used in receiving apparatus as devices for reducing interference. A method of so using the rejector is shown in Fig. 4. The rejector circuit L_2C_2 is connected or disconnected from the aerial circuit by the switch K. The aerial circuit L_1C_1 is first tuned, K being open, to the wave it is desired to receive. The circuit L_2C_2 is then similarly tuned. These two circuits are then connected in series as shown. Since the inductances L_1, L_2 and the condensers C_1, C_2 are both connected in series it can be easily seen since $L_1C_1 = L_2C_2$ that the whole aerial circuit thus formed is still tuned for the frequency for which the separate circuits L_2C_2 and L_1C_1 were previously adjusted.

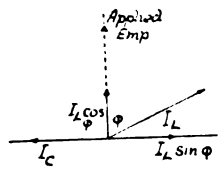

Fig. 3.

The rejector circuit is now adjusted to the frequency for which the aerial has been tuned and key K is closed. Then any signal for

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which the aerial has been tuned will find an easy path through the circuit L_1C_1 while the rejector circuit, assuming that its resistance losses are low, will present a very high impedance to the signal. On the other hand interfering signals find an easy path through the rejector, while the circuit L_2C_2 offers a high impedance to them. Interference is therefore eliminated to a large extent.

From what has already been said it is clear that in order to design the rejector circuit so as to act most efficiently as a preventer of interference it is necessary that the coil and condenser should have as low losses as possible. The presence of the

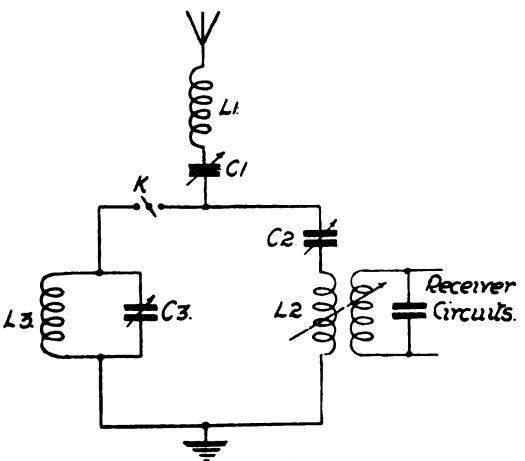

Fig. 4.

rejector circuit will reduce somewhat the strength of the current through the circuit L_2C_2 due to the signal it is desired to receive. Since the effective resistance of the rejector circuit is given by $\frac{L}{RC}$ it is clear that an easier path to earth is provided for the interfering signals when the circuit is so designed that the ratio $\frac{L}{C}$ is made as small as possible. Unfortunately, however, when this is done the effect of any resistance in the rejector circuit causes a greater loss of current in the circuit L_2C_2 than is caused for larger ratios of $\frac{L}{C}$. This is a further reason for keeping the losses in the circuit as low as possible.

When a particular signal only is to be eliminated a rejector circuit is sometimes introduced in series in the aerial circuit as shown in Fig. 5. In this case the rejector circuit is tuned to the wavelength of the signal it is desired to cut out. The circuit then imposes a high impedance for the waves of the undesired frequency, which are accordingly damped out.

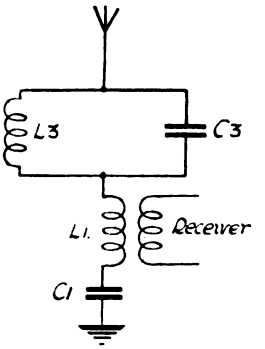

Fig. 5.

The use of reaction by a thermionic valve obviously provides a means of reducing the resistance of a rejector circuit; although it need hardly be said that such reaction will not entirely compensate for a badly-designed rejector circuit. The method is illustrated in Fig. 6, where the resistance of the rejector circuit L_3C_3 is reduced to practically zero by adjustment of the reaction coil M.

This method of reaction reduction of the rejector resistance is employed in the Hinton receiver, which has recently been patented. Receivers on this principle are largely used at Post Office high-power stations. The aerial is coupled to a tuned receiving circuit and the oscillations induced are led to the grid of the first valve. The applied voltage then produced acts across a rejector circuit (tuned to the frequency of the wave it is desired to receive) which is connected between the grid and filament of the first valve as shown in Fig. 7. The resistance of the rejector is reduced by

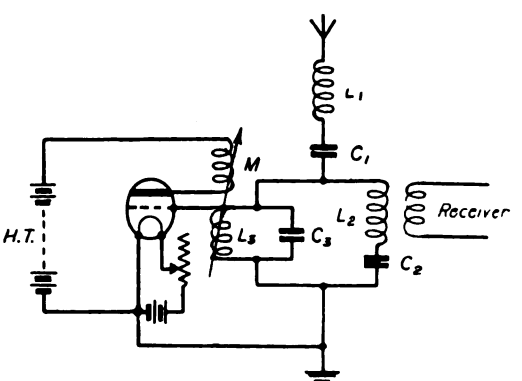

Fig. 6.

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means of a reaction coil brought from the plate circuit of the second valve. The rejector thus possesses a very high impedance

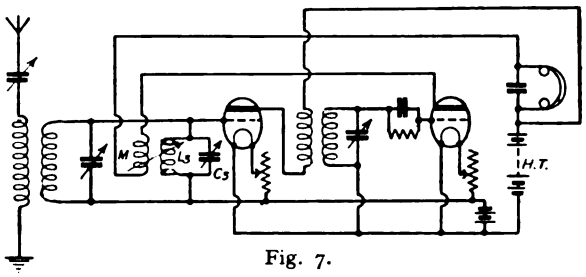

Fig. 7.

for signals of the desired frequency, while for other signals it practically short circuits the grid and filament of the first valve. The apparatus is thus highly selective.

Apart from its use as an anti-jamming device, the principle of the rejector is largely employed in radio frequency amplifiers as the well-known tuned anode method of coupling. Fig. 8 represents the first three valves of a resistance-capacity coupled amplifier. The effect of a high-frequency potential applied to grid G, is to cause a variation of the plate current in accordance with the anode current grid voltage characteristic. There is therefore a corresponding change in the potential of the plate which is equivalent to the drop in voltage across R. Thus if e_p and i_p are the instantaneous values of the change of plate voltage and current $e_p = i_p R$. This variation of voltage is, of course, transferred to the next grid by the condenser C. Now we have seen that the rejector circuit behaves as if it had a non-inductive resistance given by $\frac{L}{RC}$, hence a properly-designed rejector circuit can be substituted for the high resistance R.

This arrangement has the advantage of allowing the high-tension battery to be connected to the plate through the low resistance of the coil instead of by the high resistance R. But in addition it allows the amplifier to be made more selective, since, as we have seen, the impedance offered by the rejector depends on the tuning of the circuit. As already pointed out the tuning of the rejector circuit becomes critical when the resistance of the coil is decreased. Professor Fortescue* has pointed out that the more critical this tuning the less will be the amplification at other frequencies than that for which the rejector is tuned, and that with large values of $\frac{L}{C}$ the damping due to the rejector may render the circuit practically aperiodic. Thus a circuit having a high ratio $\frac{L}{C}$ provides the reverse of a selective amplifier. If on the other hand it is desired to make the amplifier selective this ratio must be decreased.

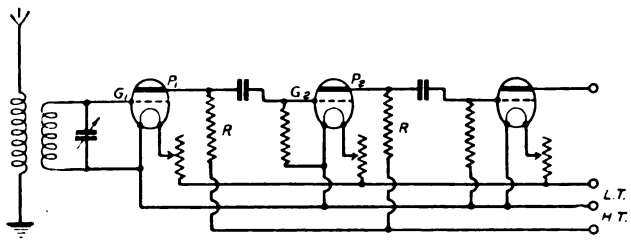

Fig. 8.

*Fortescue; "Design of Multiple-Stage Amplifiers," *Journal of Inst. of Electrical Engineers*, 58, page 66, 1920.

VALVE TESTS.

We have received a number of interesting valves for test this month, but owing to extreme pressure on space we are unable to publish the reports. Records of some crystals tested by our new method will be found on page 242.

LOW POWER TRANSMISSION.

Monsieur Perroux (8BV) has reported that he has succeeded in being heard in England by 5KO whilst using only ·003 watt input, with 3·5 volts on 1 filament, instead of the normal 5·6 volts. He is shortly going to attempt to reach England with an oscillating regenerative receiving circuit.

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Remarkable Reception of "KDKA" in Johannesburg. [R540

By Victor Hart.

IN the first week of October the wireless enthusiasts of South Africa were astonished to learn that two Johannesburg men had been receiving KDKA—the Westinghouse Electric Manufacturing Co.'s station at East Pittsburg, U.S.A.—on a loud-speaker. Messrs G. Boot and M. F. Lowe have been experimenting for a considerable period and long before the first broadcasting station in South Africa was opened in July, 1924 had worked conjointly in picking up morse from widely distant stations all over the world. Although satisfactory, such reception of dot and dash *via* headphones was just personal to themselves and it seemed a selfish form of amusement unless their friends could also participate. Moreover any listening-in to morse had reached the ordinary stage for hundreds of other experimenters in South Africa so that the logging of results led no further than friendly enthusiasts elsewhere.

Messrs. Boot and Lowe had read much concerning KDKA and of how this station had been received by British amateurs. What Britain had achieved ought surely to be possible for earnest investigators 5 000 miles from London and approximately 7 500 miles wireless distance from Pittsburg. So argued these gentlemen; and in recounting the steps which led finally to success it must not be forgotten that the definite aim was *loud-speaker* reception, of sufficient strength to be heard in every room of any ordinary house. Both are young men, neither wealthy nor with leisure from their ordinary occupations than evenings and week-ends.

Deciding upon a five-valve set (two H.F. one D. and two L.F.), the experiments to "secure" KDKA commenced in January, 1924 and several circuits were temporarily wired to discover which would best bring in Cape Town regularly on an amateur's transmission at the approximate distance of 850 miles. Each of these experiments involved complete dismantling of any rejected circuit and building up afresh with pretty well the same components, and at that early stage many uncanny peculiarities surrounding the use of ebonite were brought to light. The presumably best circuit—not the one given in the accompanying theoretical circuit—having been selected, there came the nerve-racking experience of all-night watches undertaken alternately by Mr. Boot and Mr. Lowe. Johannesburg is, to the nearest fraction of a second, seven hours in advance of Pittsburg time of day; this important fact was settled recently by regular comparison between the Pittsburg time-signal at that station's local time of 10 p.m. and the Union's Government Observatory time sent our daily from Johannesburg. (By courtesy of the astronomers on night duty in Johannesburg it was found by aid of the ordinary telephone service that the last stroke of Pittsburg 10 p.m. signal coincided with the dead fifth of a second last stroke of the official time clock in Johannesburg at 5 a.m.) The difficulty of trying for KDKA was that no definite information was then available as to what time in the evening the program commenced and finished. Nor was the exact wave-length known to anybody here other than a low wave somewhere between 100 and 120 metres.

For morning after morning from 2 a.m. until dawn attempts were made to bring in the elusive sounds, no small task when the experimenter's daily work had to be faced with but two or three hours' sleep. Convinced that the final circuit selected was correct, the next stage in progress was to modify details, step by step, so every possible arrangement of aerial was tried and then

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all the different commercial types of coils. Eventually they were reduced to winding their own coils, and between 70 and 80 were tried out up to July, 1924, when, in the early hours one morning, success was attained on one pair of phones. To bring in a loud-speaker was next tackled, and here came one of the greatest difficulties, by reason of the difficulty of procuring any satisfactory variable grid-leak. Experiments in this direction are being continued, combined with reducing capacity to the absolute minimum. Ebonite leakage has proved a stumbling block against killing capacity, and Messrs. Boot and Lowe contend attention should be concentrated by all experimenters on this important subject. The quantity of current coming through from so distant a station as KDKA is so small that no loss in the receiving set can be afforded. (Despite the universal popularity of ebonite and kindred substances for reasonable insulative purposes and ease of working in the hands of amateurs, the writer holds the opinion that porcelain or some other proved insulator may supplant ebonite).

Three days prior to forwarding these notes a few well-known wireless men were invited to a demonstration at the house, which is situated some four miles from Johannesburg Town Hall and partially screened by a hill immediately at the rear. The height of the house above sea level is, approximately, 5,800 feet. In the following remarks the corresponding Pittsburg times are given by P and figures in brackets. At 12.55 a.m. (P 5.55 p.m.) KDKA was tuned in as easily as JB (Johannesburg) the item received being a Spanish dance by the Westinghouse band: at 1.8 a.m. (P 6.8 p.m.) came a cornet solo, remarkably clear, practically perfect in purity and without distortion. At 1.15 a.m. (P 6.15 p.m.) came an orchestral selection from Mendelssohn's "Midsummer Night's Dream"; for this item the aerial lead-in was cut out of circuit and the terminal on the set joined up to a 10-foot length of ordinary 16 gauge wire slung across the room to the wood picture rails by a couple of nails, and reception was just as perfect. The announcer then gave several baseball scores, his voice in natural tones sounded as though he was speaking loudly in some other room in the house, the American accent being very noticeable; for this item the piece of strung wire was retained but the earth wire disconnected altogether without making any difference to reception. Pittsburg's afternoon session concluded just on 1.30 a.m. (P 6.30 p.m.) with a children's song, "How do you do-de-do," every word clearly rendered. This was, perhaps, the most remarkable item so far, because none of the local audience had heard this before, yet could understand all words in the refrain and chorus. This finished for a short while the demonstration until 3.5 a.m. (P 8.5 p.m.), when Mr. Lowe quickly adjusted for a few moments and a lady sang an unknown solo. Other items followed, and at 3.40 a.m. (P 8.40 p.m.) the Westinghouse band sent a splendid selection announced as "Plantation Melodies," which literally filled the house, the local audience doing their utmost to drown the band by voicing all the old choruses. Just before 5 a.m. (P 10 p.m.) the single inside house wire was cut out and an ordinary frame or loop aerial was joined up, the time signal coming over so clear and loud that it seemed incredible that the bell strokes were annihilating the thousands of miles distance; the last stroke agreed with Johannesburg local time to a second. So reception continued on the frame aerial until after sunrise at 5.30 a.m.

Some Technical Details.

Since the first week of August, 1924, Messrs. Boot and Lowe have not experienced a single failure to get Pittsburg whenever they desired, and on this point the type, height or length of aerial seemingly makes not the slightest difference. A very amateurish aerial, in form of a few yards of uncovered single wire carried a few feet above the ground and just an ordinary shell insulator each end with a roughly improvised earth connection from set to an externally dry waterpipe going into dead dry ground was equally successful, with 30 volts high tension in circuit. A lead-in from the centre of this rough aerial could not alter reception. Nor does "direction" of the frame aerial make any audible distinction, any way giving good results. The regular outside aerial has a length of 60 feet including lead-in, at a height of 35 feet and is composed of 7/22 bare copper.

The theoretical diagram provides full information of the lay-out, connections and values of components. Four tuning coils are fitted, and the equipment includes a grid bias battery, shown on the diagram between

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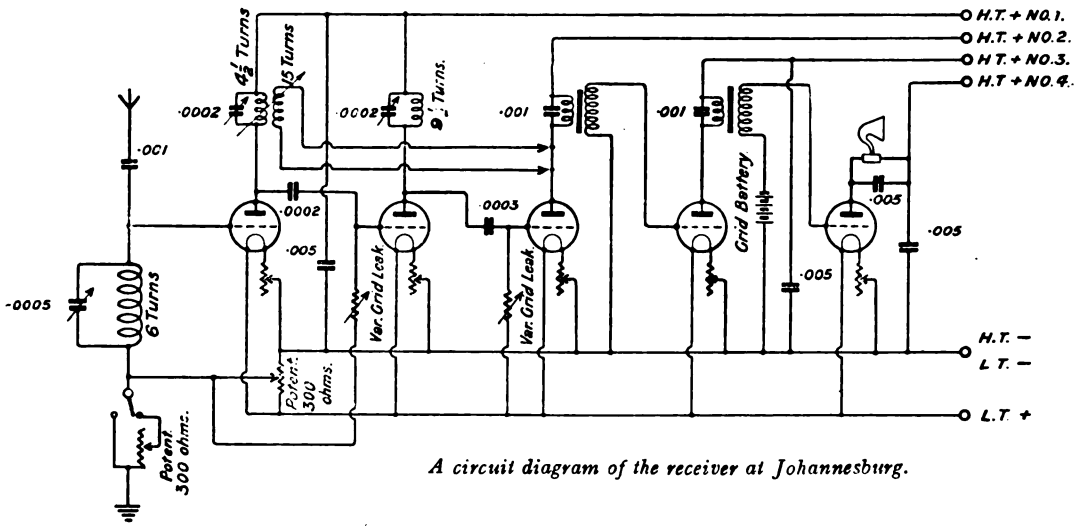
the fourth and fifth valves. At the bottom left corner is a somewhat unusual addition: in circuit with the "earth" is a 300-ohm variable resistance, with a short-circuiting switch. (An ordinary potentiometer is used.) By means of a two-way switch the coil can be put either directly to earth or through the 300 ohm potentiometer. The experimenters state that the "mystery box," so named by their friends, may be used with advantage on a 10-foot indoor aerial or frame aerial.

As regards easy tuning in of KDKA, Messrs. Boot and Lowe kindly give the following hints applicable to South African experimenters, and such may be equally useful to British enthusiasts. In this matter particular regard must be paid to the fact that the wave-length of JB (Johannesburg) is 450 metres. Insert in the three-coil holder a set of low wave-length coils and tune in JB on these coils. Leave at this setting and it will be discovered that there are two or three positions were JB comes in and disappears when the tuning condenser knobs are moved. Leave JB tuned in at any one of these "in" positions and almost exactly at that spot o. position the KDKA wave-length will come in. If the set oscillates too much, reverse the reaction coil. The Pittsburgh wave-length is 102 metres.

On some occasions a most peculiar effect has been observed which is distinct from fading or dying away. Without variation in strength or loudness the music or speech increases in speed in a series of waves, becoming faster and faster, just as though the conductor of the band or the singer in a solo had accelerated the pace. Presently, speed of reception goes back to normal and soon after the speed is reduced below the regular standard and may perhaps return to normal, or may go up and down, still in wave-like form. Any attempt to follow these speed variations by the slightest motion of the tuning controls instantly cuts out KDKA, and experience on many mornings has definitely proved it best temporarily to put up with the slight annoyance and just not attempt adjustments. The type of "fading" that so many South African experimenters have frequently noticed as regards Johannesburg and Cape Town broadcasting stations, has not been noticed on a single occasion from KDKA. Other than the rise and fall of speed above mentioned, continuous reception is invariable. Still another peculiarity relates to night and daylight reception. Most people assert that reception from distant stations is best during darkness, but the Johannesburg experimenters are positive that strength appears to be better from 4.30 a.m. to 6 a.m. corresponding to Pittsburg 9.30 p.m. and 11 p.m. At the time of writing, in Johannesburg dawn is about 5.0 and sun rises a very few minutes later.



A circuit diagram of the receiver at Johannesburg.

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Long-Distance Work.

By Hugh N. Ryan (5BV). **[R009·2**

Work with Australia and New Zealand, and extra-low-power transatlantics, are the most notable features.

LAST month I reported in detail our first work with New Zealand, and a hurried "Stop Press" note was included about the similar contact with Australia. At that time, the New Zealanders were still coming in well and regularly, whereas the Australians were only heard occasionally, and not too well.

Soon afterwards, however, the New Zealanders almost disappeared and it became a daily practice for most of our stations (as one of them expressed it) to "come on and listen to 2OD working Australia." This is practically what did happen. 2OD, having once "hooked" Australian 3BQ, worked him easily every evening for some time, while the rest of the gang listened in silent wonder.

The wonder lasted a long time, but it was not silent for long, and soon one could listen in the early evening any night, and hear, apparently, every station in Europe calling Australia.

In this connection one very curious (and happy) event took place. British 5LF had listened to the noise for several evenings, and was considerably amused at the random way in which every Continental station called Australia at once.

Most of our stations were also calling Australia, without any success. 5LF himself had never heard an Australian, and doubted the ability of anyone else (except 2OD) to do so.

However, wishing to test the transmitter one night, he started it up during this time. Instead of calling "Test"—having heard all the others doing the same—he called Australian 3BQ. He then changed over to listen to the noise again—and heard 3BQ answering him!

This would appear to be the approved method of accomplishing super-DX this year!

While the New Zealanders were, in their time, best heard at about 7 a.m., and occasionally at about 7 p.m., the Australians appear the other way round, but their best time by far is the evening. As far as I know, two-way work between here and Australia has never been accomplished in the morning, though the Australians are sometimes heard then, as, indeed, they appear to be at all sorts of queer times during the day. 6FG reports hearing a 3VV at 2 p.m., and 6LJ once heard A2DS at 4.30 p.m.!

Reception of the Australians seems to be good all over the country, most of our well-known stations regularly receiving 3BQ quite well.

A2DS has also been heard by a number of stations, though reports seem to indicate that he is not so well heard in London as elsewhere. I have not yet heard him myself. A2CM is one of the best stations in Australia, but apparently does not reach this country very well. I have heard him once myself, but I have no other reports of him. 3AL has been received by 5MO and myself.

Compared with the number of our stations who worked New Zealand, very few have worked Australia. 2OD has done by far the best work in this direction, and I think the only other successful stations, so far, are 2KF, 2SZ, 2NM and 5LF. The great trouble, of course, is that the period during which the Australians can be worked falls in broadcasting hours, and anyone who transmits on full power (or, for that matter, any power) at this time brings down upon his head the concentrated wrath of numberless people. The Post Office have given permission to most of us to use full power in the evenings, so long as no broadcasting station is on at the time, but such a time does not exist. It happens that the best time for Australian work falls between 6.30 p.m. and 7 p.m., when, hitherto, there was often an interval in the programs, but immediately the Australian work started this interval seemed to cease.

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A coincidence, doubtless, but one would have thought it a courteous action on the part of the B.B.C. to allow us that half-hour interval. It is difficult to imagine the Americans being prevented by broadcasting from working the Antipodes. As it is, we can only work Australia on Sundays.

American and Canadian work is now going on regularly. It may be my imagination, but somehow this work does not seem so satisfactory as it was last year. I suppose the difference in wave-length accounts for it. When we are listening to Americans we don't hear our own stations if they call us, and similarly, the Americans don't hear us when they are only listening for their own men. This has its great advantage in minimising QRM once we are connected, but it seems very difficult to attract the attention of the man you want.

However, judging by reports, others are not finding this as bad as I do. 5LF worked 40 Americans in the 40 days ending December 8. He has also worked an Australian and two New Zealanders in this time.

2JF is doing splendid work this winter on a hastily-assembled station. He has worked 40 times across the Atlantic, with 26 different stations, in a month, and has also worked New Zealand 4AG and received Cuban DZ and the U.S. Airship *Shenandoah.*

6NF is now QSO America and Canada, as are 6LJ, 5MO and 6VP, thus bringing several of our well-known lower-power stations of last year into the transatlantic "gang."

6LJ is now heard all over America, even on the Pacific coast, and the number of Americans he has heard approaches a thousand.

5RZ, the famous "unsuccessful transatlantic station," has forfeited his right to this title, having worked a number of Americans during December. Denmark is at last in touch with America, 7EC having worked in 1BDT several times.

One of the strongest of the Americans now working on 80 metres is 4SA. This station is in Porto Rico, which, though a considerable distance from the mainland, is included in the American fourth district. British 6NF has the distinction of being the first European to work with Porto Rico. 6NF has also, by the way, been heard in Iraq, Asia.

The record of my own transatlantic work this month is best kept well in the background, as I have been altering my transmitter, and have not sufficient time yet to do it properly. Its range at present does not seem to be as great as might be desired, judging by results across the "Pond."

While all this work has been conducted by the higher-powered stations, some interesting low-power work has also been going on in Europe, and also some very good results obtained on the reception side.

6XG is reaching out well with a T.V.T. unit as H.T., and works Finland regularly in daylight. He is receiving Americans in large numbers, and also hears Australia 3BQ.

5KO, once in the first flight of "high-power" men, is now a zero-power station as far as transmitting is concerned, but is on the air again with a receiver, and hears all there is to hear, including Australia and New Zealand. He particularly wishes me to state that his absence from the transmitting ranks is not due to his recent marriage, as the "OW" is a keen "lady Op."

6QB has managed to reach the American fifth district with 3¼ watts input! 6NH is working Finland and Luxemburg on low power and has heard A3BQ.

Mr. F. R. Neill, of Co. Antrim, Ireland, who did some very good reception of low-power English phone stations last year, is now obtaining equally good results from Americans, Australians and New Zealanders.

Before concluding, I must thank all those who have sent me in reports. The response to my request for these was very good indeed, but I hope to get even more next month. For some reason I have heard nothing from Scotland. Our old friend 5JX has now come to London, and, as far as I know, 2OA is the only active transmitter left up there.

Will someone please step into the gap and let me know what is happening in that part of the world?

Some of the northern English stations have taken to sending me weekly reports, which help me considerably. I should be grateful for more such.

What is happening in the Irish Free State? I suppose there are some enthusiasts there, and I shall be very glad to hear from them, for personal as well as public reasons. It grieves me to think that the "little bit of Heaven" knows not of DX.

Don't forget those reports. Let me have them by the 10th of each month. Foreign reports are as welcome as British ones.

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Some Crystal Test Results. [R374·009

Below we give the first results of tests on the new system explained elsewhere in this issue. Many other crystals are in hand, and will be reported as soon as possible.

WE give, in the following paragraphs, some results of crystal tests by the method now adopted. Reference to the tests is made in our "Editorial Views" and also in our article on p. 200. But we should like to repeat that the results must be considered provisional at present. Recapitulating briefly, the method is to apply an H.F. voltage of frequency about 795 000 (377 metres), to measure the input and output power, and to find from these the equivalent H.F. resistance (considered as a shunt across the circuit) and the actual efficiency as a power transformer. The crystal works into a load of 10 000 ohms, which we consider an average figure for the audio-frequency impedance of average present-day phones; and voltages varying from 1·0 to 0·1 are applied. Five points, taken as they come, are tested at ·5V, and a sixth is tested at various voltages.

Exolo.

A nice clean-looking galena, grain about 30 to the inch. Two samples supplied by Messrs. H. De Kaningh, 14-15, D'Arblay St., W.1, sold at 1s. One sample tested. Five points, taken as they came and tested at ·5V input, gave percentage efficiencies of 31, 22, 32, 31, 22 (av. 29). The H.F. resistance was fairly high for most points, being 27 000, 21 000, 11 000, 70 000, 5 500 for the five points. A sixth point tested at varying voltage, gave 28 per cent. at 1V and 24 at ·3V, the H.F. resistance varying from 13 000 to 34 000. Owing to the comparatively high resistance, we could not get figures for ·1V, as the input was too low to measure. The output was about $\frac{1}{10\,000\,000}$ watt: the input was, of course, larger, but as explained in our article on the subject, measurements at high frequency are not so easy as for D.C.

Radiolyte (long range.)

One sample of each two types, submitted by H. Renshaw, 174, Oxford Rd., Manchester. Test of the other type deferred to a later issue. Sample about $\frac{1}{4} \times \frac{1}{4} \times \frac{3}{8}$ in., supplied in tube at 1s. 6d. Of typical appearance; grain about 40 to the inch. Five points taken as they came gave percentage efficiencies of 33, 54, 51, 40, 45 (av. 45); the H.F. resistances were 8 800, 12 500, 14 000, 21 000, 11 500. A sixth point tested at various voltages was free from the usual pronounced tendency to exhibit a falling off in efficiency at lower voltages: it ranged between 40 and 50 per cent. throughout. The H.F. resistance, on the other hand, rose in the usual manner from 5 400O at 1V to 25 000O at 0·1V.

Dearnite.

Sample submitted by Mr. J. A. Dearnley, 8, Belle Vue Street, West Gorton, Manchester. Sample about $\frac{1}{4}$ in. cube, ready-mounted in Woods' metal, supplied at 1s. 6d. A lustrous large-grained galena (16 or 20 to the inch). Five points, taken as they came, showed a most excellent per cent. efficiency, the values being 20, 75, 61, 60, 72 (av. 58). Leaving out the one comparatively poor point, the average was 67 per cent. The resistances were 7 000, 13 000, 13 000, 17 000, 14 000: it is obvious that the point of lower efficiency was passing too much reverse current. A sixth point tested at various voltages gave an almost constant efficiency of 65-75 per cent. right down to ·2V: the input power at ·1V was below measurement with present apparatus. H.F. resistance varied between 10 000O and 27 000O, increasing steadily as the applied voltage fell.

Ethita.

Submitted by "Bright" Co., Crouch End, N.8. A fairly lustrous galena of large grain (16 or less to the inch.) Sample about $\frac{5}{16} \times \frac{5}{16} \times \frac{3}{8}$ in., supplied at 6d—1s 6d. Five samples submitted, one taken at random. Five points taken as they came and tested at ·5V showed percentage efficiencies of 85, 64, 93, 55, and 96 (av. 75). Some of these were so exceedingly high that we suspected an error somewhere, but we could detect nothing wrong. The H.F. resistances were 21 000, 24 000, 31 000, 16 000, and 27 000. A sixth point tested at various voltages gave rather lower efficiencies, with the peculiarity that the efficiency *increased* at low voltage: it varied between 48 and 87. The H.F. resistance was low at large voltages (7 100) and increased to 47 000 at ·1V. It would seem that the higher voltages caused reverse current.

An exceptionally efficient crystal.

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A Short English-Esperanto Dictionary of Radio Terms. [R800

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With the aid of this comparatively small list of words, readers who mastered the grammatical construction of the language given in our last issue, will realise that they can express much more than might appear to be the case, since, by substituting the adjectival ending "a" for the noun ending "o," and so on, many words may be added to the vocabulary.

THE following Dictionary contains most of the words and phrases used in amateur radio, with their Esperanto equivalents. Acknowledgment is made to the *Radio Annuaire,* published in Paris, whose five-language supplement of radio terms, with Esperanto addition compiled by Dr. P. Corret, was of great assistance.

A

Accumulator, akumulatoro.
adjustable, alĝustigebla, variigebla.
aerial, antenna, anteno; **artificial,** artefarita; **cage,** kaĝforma; **directional (fixed),** direktita; **frame,** kadra anteno, kadro; **funnel-shaped,** funela; **horizontal,** horizonta; **L-shaped,** L-forma; **open,** nefermita; **receiving,** riceva; **sausage,** kolbasa; **sending, transmitting,** senda; **trailing,** pendanta; **T-shaped,** T-forma; **umbrella-shaped,** ombrela; **vertical,** vertikala.
alternating, alterna;—**current,** alterna kurento.
alternator, alternatoro, alternilo; **high-frequency—,** altfrekvenca a.; **induction—,** a. kun turna fero; **motor alternator disc set,** motoralternatora grupo kun diska sparkilo; **multiphase, polyphase—,** multfaza a.; **turbine—,** turbo-alternatoro; **two-phase—,** dufaza a.
aluminium, aluminio.
amateur, amatoro; **wireless, radio—,** senfadena, radio-amatoro.
ammeter, ampermetro; **alternating current—,** alternkurenta a.; **direct current—,** kontinu-kurenta a.; **moving coil—,** movbobena a.
ampere. ampero; **milli—,** miliampero;—**turns,** amperturnoj.
amplification, (*action*) amplifo, amplifado, (*state*) amplifeco; **high frequency,** altfrekvenca; **low frequency,** malaltfrekvenca; **dual,** duala.
amplifier, amplifikatoro, amplifilo; **high, low, frequency—,** altfrekvenca, malaltfrekvenca, amplifikatoro; **magnetic—,** magneta a.; **resistance—,** rezistanca a.; **transformer—,** transformatora a.
amplify, to, amplifi.
amplitude, amplitudo.
anode, anodo; **tuned—,** agordita anodo.
antenna, anteno, (*see* **Aerial**); **damping of—,** antena amortizo; **radiating—,** radianta anteno; **—support,** antena portilo.
aperiodic, aperioda.
apparatus, aparato.
arc, arko.
asynchronous, asinkrona.
atmospherics, atmosferaĵoj, atmosferaj perturboj.
audio-frequency, malalta frekvenco.
audible, aŭdebla; **audibility,** aŭdebleco.
audion, aŭdiono, valvo.
autodyne, aŭtodino.
automatic, aŭtomata.

B

Bakelite, bakelito.
balanced, kompensita; **—crystal detector,** kompensita kristala detektoro; **—receiver,** kompensita ricevilo.
balancing signals, kompensitaj, (*or* ekvilibritaj) signaloj.
bare wire, nuda fadeno.
battery, baterio, pilaro; **anode, filament,—**; anoda, filamenta baterio; **high tension, low tension,—,** altatensia, malaltatensia, baterio; **storage—,** akumulatoro.
beats, batoj.
broadcast, to, brodkasti, disaŭdigi, dissendi.
broadcasting (*noun*), brodkasto, brodkastado; (*adj.*) brodkasta: **—station,** brodkasta stacio.
buzzer, zumilo.

C

Calibrate, to, kalibri; **calibration,** kalibro, kalibraĵo.
call, to, voki; **—sign,** voksignalo.
capacitance, kapacitanco.
capacity, kapacito; **aerial—,** antena k.; **resistance—,** rezistanca k.; **self—,** mem-k.; **stray capacities,** superfluaj kapacitoj.
capacity earth, counterpoise, kontraŭpezo.
carbon, karbono.
carborundum, karborundo.
carrier wave, portanta ondo.
cascade, kaskado; **—formation,** kaskada formo; **in—,** kaskade.
cathode, katodo; **incandescent—,** inkandeska katodo.
cat-whisker, kontakt-fadeneto por kristalo, "katlipharo."
cell, pilo; **battery,** pilaro, baterio; **dry cell,** seka pilo.
change of connections, komuto; **—for receiving,** k. por ricevo; **—for transmitting,** k. por sendo.
change-over switch, komutatoro, komutilo.
charge to, ŝarĝi.
charging switch, interuptoro por ŝarĝo, ŝarĝinteruptoro.
choke coil, reaktanca bobeno, ŝokbobeno; **air core protecting—,** aerkerna—.
choking coil, indukta bobeno.
circuit, cirkuito; **closed oscillating—,** fermita oscila c.; **grid—,** krada c.; **intermediate—,** intera (*or* pera) c.; **open oscillation—,** nefermita oscila r.: **short—,** mallonga c.
circuit breaker, cirkuita interuptoro.
close (*or* **tight**) **coupling,** apuda kupleco.
coarse, kruda.
coefficient, koeficiento, grado; **coupling—,** kupla g.
coherer, koheroro, koherilo; **filings—,** fajlaja k.; **granular—,** grajna k.

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coil, bobeno, spulo; **air core protecting choke—,** aerkerna reaktanca b.; **anode—,** anoda b.; **basket** (*or* **spiderweb**)**—,** korba (araneaja) b.; **choking—,** indukta b.; **coupling—,** kupla b.; **cylindrical—,** cilindra b.; **honeycomb—,** ĉelara, b.; **induction—,** induktanca b.; **loading—;** aldona (longiga) b.; **measuring—,** mezura b.; **plug-in—,** enŝtopa b.; **solenoid—,** solenoida b.; **Tesla—,** Tesla b.
coil-holder-stand, bobenujo, boben-tenilo.
commutator, komutatoro, komutilo.
compensator, kompensatoro, kompensilo.
component (**part**), komponaĵo.
compound, kompunda, malsimpla.
condenser, kondensatoro, kondensilo; **adjustable—,** alĝustigebla k.; **aerial tuning—,** antenagorda k.; **blocking—,** bloka k.; **closed circuit—,** fermita k. cirkuita; **secondary circuit—,** sekundaria k. cirkuita; **twin-coupled—,** duopa k.; **variable—,** varia, variigebla k.; **vernier—,** verniera k.
conduct, to, konduki; **conductive,** kondukiva; **conductivity,** kondukiveco.
connect, to, konekti; **connection** (*action*) konekto; (*thing*) konektaĵo.
constant, konstanto; **dielectric—,** dielektrika k.
continuous wave, kontinua onda.
control, to, kontroli.
converter, konvertitoro konvertilo.
copper, kupro; **tinned—,** stanita k.; **—pyrites,** kupra pirito.
coulomb, kulombo.
counterpoise, capacity earth, kontraŭpezo.
couple, to, kupli; **coupled,** kuplita; **inductively—,** induktokuplita.
coupler, kuplilo; **vario-coupler,** vario-kuplilo.
coupling, (*action*) kuplo, kuplado, (*state*) kupleco; **close** (*or* **tight**)**—,** apuda k.; **electromagnetic, electrostatic,—,** elektromagneta, elekrostatika, k.; **fixed—,** fiksa k.; **inductive—,** indukta k.; **loose—,** malapuda k.; **reaction—,** reakcia k.; **variable—,** varia, variigebla k.
coupling coefficient, kupla koeficiento.
crystal, kristalo; **—detector,** kristala detektoro.
current, kurento; **alternating—,** alterna k.; **direct—** kontinua k.; **high frequency—,** altfrekvenca k.; **low frequency—,** malaltfrekvenca k.; **primary alternating—,** primaria alterna k.
current interrupter, kurenta interuptoro
current loop, ventro de intenseco; **current node,** nodo de intenseco.
curve (*graph*), kurvo; **characteristic—,** karakteriza k.
cycle, ciklo.

D

Damped waves, amortizaj ondoj.
damper, silentigilo.
damping, amortizo; **high—,** granda a.; **—of antenna,** antena a.
decohere, to, malkoheri; **decoherer,** malkoherilo, dekoheroro.
decrement, dekremento.
decremeter, dekremetro.
detector, detektoro, detektilo; **balanced crystal—,** kompensita kristala d.; **crystal—,** kristala d.; **magnetic—,** magneta d.; **perikon—,** perikona d.; **thermo—,** termo-d.; **thermo-electric—,** termo-elektra d.; **valve—,** valv-d.
device, aranĝo.
dial, ciferplato.
diaphragm (*of telephone receiver*), plato (de telefonilo).
dielectric, dielektriko (*noun*).
dielectric (*adj.*), dielektrika; **—constant** (**specific inductive capacity**), d. konstanto; **—strength,** d. firmeco; **—stress,** d. streco.
diode (*two-electrode valve*), diodo.
diplex, dipleksa.
direct current, kontinua kurento.
directional aerial (*fixed*), direkita anteno; (*moveable*) direktebla anteno.
direction finder, direkto-trovilo.
disc, disko.
discharger, sparkilo; **asychronous—,** asinkrona s.; **synchronous—,** sinkrona s.
distort, to, distordi; **distortion,** distordo.
disturbances, perturboj.
double-pole, dupolusa.
double-throw, duvoja.
dual amplification, duala amplif-o, -ado, -eco
dull emitter (**valve**), malhela (valvo).
duplex, dupleksa.
dynamo, dinamo; **compound,—** kompunda d.; **self-excited—,** memekscita do; **separately excited—,** d. kun sendependa ekscito; **shunt—,** ŝunta (*or* deriva) d.

E

Earpiece (*of telephone receiver*), orelpeco; **—cap,** ĉapo de o.
earth, tero; **capacity—,** kontraŭpezo: **—connection,** t. konektaĵo.
ebonite, ebonito.
effective, efektiva.
efficiency, rendimento, efikeco.
electricity, elektro.
electrode, elektrodo.
electrolytic, elektroliza.
electromagnetic, elektromagneta.
electron, elektrono; **—emission,** elektrona elsendo.
electrostatic, elektrostatika.
emission, elsendo.
endodyne, aŭtodino.
energy, energio.
ether, aether, etero.
excite, to, eksciti; **exciter,** ekscitatoro, ekscitilo.
experiment, to, eksperimenti; **experimenter,** eksperimentisto.

F

Factor, faktoro; **power—,** f. de potenco.
farad, farado; **microfarad,** mikrofarado.
feed-back, reakcio.
fibre, fibro.
field, kampo; **electric, magnetic,—;** elektra, magnetak.
field break switch, interuptoro de kampo.
filament, filamento; **bright, dull,—;** hela, malhela, f.
filter, filtrilo.
fine tuning, delikata (*or* subtila) agordo.
flat tuning, neakuta agordo.
flexible, fleksebla.
formula, formulo.
frame (*aerial*), kadro, kadra anteno.
frequency, frekvenco; **group—,** ondara f.; **high** (*or* **radio**)**—,** alta f.; **low** (*or* **audio**)**—,** malalta f.; **wave—,** onda f.
function, to, funkcii.

G

Galena, galeno.
galvanometer, galvanometro.
generate, to, generi.
generator, generatoro, generilo; **continuous current—,** g. de kontinua kurento.

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grid, krado; **—circuit,** krada cirkuito; **—leak,** krada rezistanco.
ground, tero.

H

Hammer break, martela interuptoro.
harmonic, harmoniko.
henry, henrio; **microhenry,** mikrohenrio.
Hertzian wave, Hertza ondo, elektromagneta ondo.
heterodyne, heterodino; **self—,** mem-heterodino, aŭtodino.
high damping, granda amortizo.
high frequency, alta frekvenco; **—group,** alt-frekvenca grupo.
high tension, alta tensio.
hook-up, cirkuito.
hot-wire ammeter, varmfadena ampermetro.
howl, to, ululi; **howling,** ululado.

I

Impedance, impedanco.
Inductance, induktanco; **aerial—,** antena i.; **aerial tuning—,** antenagorda i.; **primary, secondary—,** primaria, sekundaria i.
induction, indukto; **self- —,** mem- i.; **—alternator,** alternatoro kun turna fero.
inductive, indukta; **—transmitter,** induktotuplita sendilo.
inert, inerta; **inertia,** inerteco.
inner primary (*of transformer*), eniro de primario.
inner secondary (*of transformer*), eniro de sekundario.
input, enmeto.
insulate, to, izoli; **insulated,** izolita; **insulation,** izoleco.
insulator, izolatoro, izolilo; **flexible—,** fleksebla i.; **leading-in—,** i. de eniro.
interference, interfero.
interruptor, interuptoro, interrompilo; **current—,** i. de kurento; **electrolytic—,** elektroliza i.; **induction—,** i. de indukta bobeno; **mercury—,** hidrarga i; **mercury turbine—,** hidrarga turbo-i.
intervalve, intervalva.
iron core, fera kerno, ferkerno.
iron pyrites, ferpirito.

J

Jack, ĵako.
jam, to, interferi, ĵami; **jamming,** interfero, ĵamo, -ado.
jigger, oscila transformatoro, ĝigero.
joule, ĵulo.

K

Key, manipulatoro, senda klavo.

L

Laminations, lamenaĵoj; **laminated,** lamenita.
lead (*wire connection*), konduktoro, kondukilo.
lead-in, enira fadeno.
Leyden jar, Lejdena botelo.
licence, permeso; **receiving, transmitting,—,** riceva, senda p.
lightning arrester, fulmŝirmilo.
log, to, registri; **— -book,** registro-libro.
loop (*antenna*), kadro.
loud-speaker, laŭtparolilo; **laŭtigilo.**
low frequency, malalta frekvenco.
low-loss (condenser), (kondensatoro kun) malgranda perdo.

M

Magnet, magneto.
make and break, interuptoro.
mast, masto; **compound—,** dismuntebla m.; **portable—,** portebla m.
maximum, maksimumo.
measuring coil, mezura bobeno.
mercury, hidrargo.
meter, metro; **frequency—,** frekvenca m.
mica, glimo.
micrometer, mikrometro.
microphone, mikrofono; **carbon disc—,** karbon-diska m.; **carbon rod—,** karboncilindra m.; **contact—,** kontakta m.; **granular—,** grajna m.; **powder—,** pulvora m.
minimum, minimumo.
modulate, to, moduli; **modulation,** modulo, modulado, moduleco.
Morse code, Morsa kodo.
motor, motoro; **alternating current—,** altern-kurenta m.; **asynchronous—,** asinkrona m.; **induction—,** indukta m.
motor alternator disc set, motor-alternatora grupo kun diska sparkilo.
mount, to, munti; **to dismount,** dismunti.
moving coil ammeter, movbobena ampermetro.
multiphase, multfaza.
multiple, multopa, multobla.
multi-stage, multopa, multetaĝa.
multi-vibrator, multivibrilo.
mutual conductance, komuna konduktanco.

N

Natural oscillation, fundamenta oscilo.
negative, negativa.
neon, neono; **neon tube,** neona tubo.
node, nodo; **current—,** n. de intenseco; **potential—,** n. de tensio.
non-inductive shunt, neindukta, senindukta, ŝunto.
note magnifier, sonfortigilo, malalfrekvenca amplifikatoro.

O

Ohm, omo; **megohm,** megomo.
operate, to, funkciigi; **wireless operator,** senfadenisto, radiisto.
open radiating circuit, nefermita radianta cirkuito.
oscillate, to, oscili.
oscillation, oscilo; **to break into—,** ekoscili; **fundamental** (*natural*)**—,** fundamenta o.; **self- —,** mem-o; **—transformer,** oscila transformatoro; **open—circuit,** nefermita oscila cirkuito; **closed—circuit,** fermita o. cirkuito.
oscillator, oscilatoro, oscililo.
outer primary (*of transformer*), eliro de primario.
outer secondary (*of transformer*), eliro de sekundario.
output, elmeto.
overload, troŝarĝo.

P

Panel, panelo; **control—,** kontrol-panelo.
parallel, paralela; **connected in—,** konektita paralele.
perikon, perikono.
phase, fazo.
plate, plato, anodo; **—circuit,** plata cirkuito.
plug, ŝtopilo; **coil—,** bobena ŝ.
plug-in, to, enŝtopi; **plug-in coil,** enŝtopa bobeno.
pole, poluso.
polyphase, multfaza.
porcelain, porcelano.
positive, pozitiva.
potential, tensio; **—loop,** ventro de t.; **—node,** nodo de t.
potentiometer, potenciometro.
power factor, faktoro de potenco.

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primary, primario, primaria.
propagation of waves, propagado de ondoj.

Q

Quenched spark, estingita sparko; **—gap,** estinga sparkilo.

R

Radiate, to, radii, radiadi; **radiating,** radianta.
radiation, radiado.
radio, radio; **—amateur,** r.-amatoro, radiulo; **—" fan,"** radiamanto; **—operator,** radiisto; .. **-telegraphy,** r.-telegrafio; .. **-telephony,** r.-telefonio; **—station,** r.-stacio, radiejo.
radio-frequency, radio-frekvenco, alta frekvenco.
radiogoniometer, radiogoniometro.
range, trafpovo.
ratio, proporcio.
reactance, reaktanco.
reaction, reakcio.
receiver (*person*), ricevanto, ricevisto.
receiver (*object*), ricevilo, ricevaparato; **balanced—,** kompensita r.; **continuous wave—,** r. por kontinuaj ondoj.
receiver arrangement, riceva aranĝo.
receiving apparatus, set, ricevilo, ricevaparato.
reception, ricevo, ricevado.
recorder, recording apparatus, mem-skribanta aparato, mem-skribilo.
rectification, rektifo, rektifado.
rectifier, rektifikatoro, rektifilo.
rectify, to, rektifi.
reflex, refleksa.
regeneration, regenero, reakcio.
regulating resistance, reostato de kampo.
rejector (*adj.*), rejeta.
relay, to, relaji.
relay, relajo; **high tension—,** altatensia r.; **key—,** r. de la manipulatoro, senda klavo.
resistance, rezistanco; **grid—,** krada r.; **high, low—,** alta, malalta r.; **insulation—,** izola r.; **regulating—,** reostato de kampo; **variable—,** varia r., reostato; **starting—,** starta reostato.
resonance, resonanco; **—curve,** resonanca kurvo.
resonator, resonatoro.
rheostat, reostato; **filament—,** filamenta r.
ripple, subondeto; **—elimination,** subondeta elimino.
root mean square (value), efika (valoro).
rotary spark gap, turna sparkilo.
rotor, rotoro, turnbobeno.

S

Saturation, satureco.
screened, ŝirmita.
secondary, sekundario, sekundaria.
selective, selektiva; **selectivity,** selektiveco.
self-excited dynamo, mem-ekscita dinamo.
self-capacity, mem-kapacito.
self-induction, mem-indukto.
self-oscillation, mem-oscilo.
send out waves, to, elsendi ondojn.
sending apparatus, sendilo, sendaparato.
sending key, manipulatoro, senda klavo.
series (*adj.*), seria; **connected in—,** konektita serie.
sharp tuning, akuta agordo.
shellac, ŝelako.
short circuit, mallonga cirkuito.
shunt, ŝunto; **highly inductive—,** altindukta ŝ.; **non-inductive—,** neindukta, senindukta, ŝ.
signals, signaloj; **balancing—,** kompensitaj, ekvilibritaj, s.
sliding contact, ŝova kontakto.
smooth, to, glatigi.
solder, to, soldi, brazi.
span, vantaro.
spark, sparko; **quenched—,** estingita s.; **rotary—,** turna s.
spark gap, sparkilo; **multiple—,** multopa s.; **quenched—,** estinga s.
sparking distance, sparka distanco.
specific inductive capacity (dielectric constant), dielektrika konstanto.
spindle, spindelo.
spreader, apartiga stango.
stable, stabila; **stability,** stabileco; **stabiliser,** stabiligilo.
standard, normo; **standardise, to,** normigi.
starter, startilo.
static, atmosferajoj.
station, stacio.
stator, statoro, fiksbobeno.
storage battery, akumulatoro
strays, atmosferaj perturboj, atmosferajoj.
strength, firmeco, forteco; **dielectric—,** dielektrika f.
stress, streĉo; **dielectric—,** dielektrika s.
super-heterodyne, super-heterodino.
super-regeneration, super-reakcio.
supersonic, supersona.
sustained wave, kontinua ondo.
switch, to, (*general term*) ŝalti (*change-over*) komuti, (*cut out*) interupti.
switch (*general term*), ŝaltilo; **change-over—,** komutatoro, komutilo; **cut-out—,** interuptoro, interuptilo; **automatic—cut-out,** aŭtomata i.; **charging—,** ŝarĝ-i.; **field break—,** i. de kampo; **high tension—,** altatensia i.; **double-pole—,** dupolusa k.; **double-throw—,** duvoja k.; **wave-changing—,** ondŝanĝa k.; **rotary—,** turna k.
switchboard, ŝalta, komutatora, interuptora, tabulo.
synchronous discharger, sinkrona sparkilo.
synthetic, sinteza.
syntonisation, sintonizo, agordo.
syntonise, to, sintonizi, agordi.
syntony, sintonio.

T

Tap, to (a coil), spili, tapi; **tappings,** spilaĵoj, tapaĵoj.
tapper, frapilo.
telautograph, telaŭtografo.
telegraph, telegrafo.
telephone, telefono; **—receiver,** telefonilo.
tension, tensio; **high, low—,** alta, malalta t.; **high—relay,** altatensia relajo.
terminal, binding post, borno, klemo
tetrode (*four-electrode valve*), tetraodo.
thermionic, termiona.
thermo-couple, termo-kuplo.
Thomson's formula, formulo de Thomson.
three-electrode valve, trielektroda valvo, triodo.
tickler, tiklilo.
transformer, transformatoro, transformilo; **air-core—,** aerkerna t.; **high frequency—,** altfrekvenca—; **low frequency—,** malaltfrekvenca; **high ratio—,** altproporcia t.; **low ratio—,** malaltproporcia t.; **oscillation—(jigger),** oscila t. (ĝigero); **plug-in—,** enŝtopa t.
transmission, sendo, elsendo, sendado, elsendado.
transmit, to, sendi, elsendi.
transmitter, (*person*), sendanto, sendisto.
transmitter (*object*), sendilo, sendaparato.
transmitting apparatus, sendaparato, sendilo.

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trembler, martela interuptoro.
triode (*three-electrode valve*), triodo.
tube (*valve*), valvo, tubo, lampo.
tune, to, agordi, sintonizi; **to re-tune,** reagordi; **to tune out,** foragordi, malagordi.
tuned, agordita, sintonzita; **flatly—,** neakute a.; **sharply—,** akute a.; **untuned,** neagordita.
tuner, agordilo, sintonizilo.
tuning, agordo, sintonizo; **coarse—,** kruda a.; **fine—,** delikata, (*or* subtila); **flat—,** neakuta a.; **sharp—,** akuta a.; **—coil,** agorda bobeno.
turn (*of a coil*), volvo (de bobeno).

U

Undamped wave, kontinua ondo.

V

Vacuum tube, vakua tubo.
valve; valvo, tubo, lampo; **2-electrode—,** diodo; **3-electrode—,** triodo; **4-electrode—,** tetraodo; **bright emitter—,** hela v.; **dull emitter—,** malhela v.
variable, varia, variigebla, alĝustigebla.
variometer, variometro; **vario-coupler,** vario-kupilo.
vary, to, varii.
velocity, rapideco.
vernier, verniera.
volt, volto; **voltage,** tensio.

W

Watt, vato; **kilowatt,** kilovato.
wave, ondo; **carrier—,** portanta o.; **continuous waves,** kontinuaj ondoj; **damped —s,** amortizaj o.; **electromagnetic —s,** elektromagnetaj o.; **Hertzian —s,** Hertzaj o.; **undamped —s,** kontinuaj o.
wave frequency, ondfrekvenco.
wavemeter, ondometro.
wire, fadeno, drato; **bare—,** nuda f.; **flexible—,** fleksebla f.; **insulated—,** izolita f.; **solid—,** solida f.; **stranded—,** dividita f.
wiring (*collection of wires*), fadenaro; (*method of wiring*), fadenaranĝo; (*action*), fadenado.
wireless, senfadena.

X

X's, atmosferaĵoj.

An Imaginary Conversation between two Amateur Transmitters.

ENGLISH.

Imaginary Conversation.

Hullo! 6CV, Hullo! Hullo! 8CF replying. I have been trying to raise you all night. Your speech is quite clear but under-modulated. Before we start on radiation tests you had better increase it a little. You are R5 and being jammed pretty badly by two other British stations both working on the same wave-length and grinding out gramophone records. I am being troubled by my generator, I think the commutator requires attention. Do you notice any ripple? 8CF over to 6CV.

Hullo! 8CF, 6CV replying. Thanks very much for report. Please stand by for one minute and I will try and increase modulation a little. The wave length will alter slightly. Hullo! Hullo! I hope that is better. With the particular system of control I am employing at the moment, modulation cannot be increased any more without speech breaking. No, I can hear no generator noise from you. 6CV over for you.

Hullo! 6CV, 8CF replying. I am sorry, but you are still jammed. I managed to get your first remarks and you have increased modulation satisfactorily. Will you please try again? 8CF over to 6CV.

Hullo! 8CF, 6CV answering. Thanks very much. This represents twenty minutes wasted. I am going to try and stop some of these gramophones. Please stand by and I will call you later. 6CV switching off to you.

ESPERANTO.

Imaga Konversacio.

Halo, C6V, Halo! Halo! 8CF respondas. Mi penis trafi vin dum la tuta nokto. Via parolo estas tute klara sed sub-modulata. Antaŭ ol ni komencos provojn pri radiado, vi devus preferinde iom plifortigi ĝin. Vi estas R5 kaj sufiĉe forte ĵamata de du aliaj Britaj stacioj, kiuj ambaŭ uzas la saman ondolongon kaj elgrincigas gramofonaĵojn. Mi estas ĝenata per mia generatoro; mi kredas, ke mia komutatoro bezonas atenton. Ĉu vi rimarkas ian subondeton? 8CF aŭskultas al 6CV.

Halo, 8CF, 6CV respondas. Dankon multe pro raporto. Bonvolu atendi dum unu minuto, kaj mi provos plifortigi modulon iomete. La onda longo estos iom ŝanĝita. Halo! Halo! Mi esperas, ke tio estas plibona. Per la aparta kontrol-sistemo, kiun mi uzas nunmomente, la modulo no estas plifortigebla sen rompo de la parole. Ne, mi aŭdas nenian generatoran bruon de vi. 6CV aŭskultas al vi.

Halo, 6CV, 8CF respondas. Bedaŭrinde, vi estas ankoraŭ ĵamata. Mi kaptis viajn unuajn rimarkojn, kaj vi kontentige plifortigis vian modulon. Bonvolu provi denove. 8CF aŭskultas al 6CV.

Halo, 8CF, 6CV respondas. Dankon multe. Jen dudek minutoj perditaj. Mi penos silentigi kelkajn el tiuj gramofonoj. Volu atendi, kaj mi vokos vin poste. 6CV finis kun vi.

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Letters of interest to experimenters are always welcome. In publishing such communications the Editors do not necessarily endorse any technical or general statements which they may contain.

International Radio Week.

The Editor, E.W. & W.E.

REPORTS ON EVENING TRANSMISSIONS.

SIR,—May we beg your readers, while the impressions are still fresh in memory, to forward brief reports on the quality of reception they experienced of the 10.30—11.30 p.m. transmissions, whether such reception was :—

(A) Direct from the country broadcasting ;
(B) *Via* the B.B.C. relays.

Observations, opinions, and criticisms (especially constructive) are invited, since such comment will be invaluable.

Out of deference to the expressed wish of the B.B.C. practically no preliminary publicity was given to the institution of these evening transmissions. Consequently, great numbers of the public are doubtless quite unaware of the aims and objects of the movement, and it may be desirable here to mention that the aim is to bring nations into closer touch by means of national programmes broadcast by each country in turn for the benefit of other participating countries. Such programmes, containing amongst other items addresses by leading personalities, native music by native composers, and other material peculiar to the country broadcasting, will, it is hoped, tend towards the creation of better international understanding and goodwill.

These transmissions must not be confused with the 3—5 a.m. scientific tests, with which they have little in common. The evening transmissions were designed for the purpose stated, rather than for their scientific value, and were arranged so that even the crystal-user might enjoy a " glimpse " of foreign lands.

The criticism of the lady who has written charging the promoters with causing the bad weather and consequent loss of life through storm-havoc is unkind, but everyone is entitled to his, or her, own opinion.

All communications then will be welcomed—even a line on a postcard.

THE WIRELESS RETAILERS' ASSOCIATION.
CLIFFORD & CLIFFORD,
Hon. Secretaries.

[Will readers please apply direct to the Association, at 70, Finsbury Pavement, E.C.2.—ED., E.W. & W.E.]

Grid Rectification.

The Editor, E.W. & W.E.

SIR,—Might I be allowed to venture a few remarks on the very interesting article in your December issue by H. J. Barton Chapple on Grid Rectification?

In the first place it would have been interesting to have had a series of curves substituting a broadcast station for the buzzer used in his tests. The great majority of the valves in use are not concerned with buzzers. If distortion by any chance were introduced by the use of a grid-leak of high value it would pass unnoticed—not so in the case of voice or music.

The characteristics of the valve used by Mr. Chapple, shown in Fig. 3, seems to me to have a very low mA emission. Many of the valves to-day run much higher, from 4 to 10, with 100 volts on the anode ; and a series of curves with such a valve would have been interesting.

Lastly, I should be curious to know if Mr. Chapple would get the same results on a multi-valve set. Let him put, say five valves ahead of his detector and then try a 5MO grid-leak, I believe he would find that except for very DX work the results would not be satisfactory.

I made a few experiments last summer with a superheterodyne to test the relative merits of grid-leak and anode current rectification : using in the latter case a grid-biasing arrangement through potentiometer similar to that shown by Mr. Chapple in Fig. 7.

With fixed grid-leaks I got the best results with one of a valve ½MO ; but working on the lower bend of characteristic with negative bias gave still better results—the mA emission of my valves at 100V being never less than four.

Cannes. H. EMMONS.

The Editor, E.W. & W.E.

SIR,—*Re* article in December number on rectification, I think the conclusions drawn by the author as to optimum values of grid leak, grid condenser and anode voltage for the Ora valve, must be accepted with a certain amount of caution. In the first place " spark " signals were used for the tests, whereas a set is usually required almost exclusively for reception of C.W. and telephony.

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Secondly, I can find no mention of the wave-length employed, which will obviously affect the optimum value of grid condenser.

In connection with the article on a 3—5 metre receiver, the author says: "Once a set is just on the point of oscillating . . . the open question remains—Is it worth while reducing the losses any further?" Now what is the general opinion on this point? Does the use of reaction up to oscillation point compensate for all losses in a single valve set, *e.g.*, dielectric losses, eddy current losses, etc., or only for that due to H.F. resistance? If so, it seems rather a waste of time to design super-efficient inductances, etc., for short-wave work.

Earlsfield. E. LESTER SMITH.

Co-operation Needed.

The Editor, E.W. & W.E.

SIR,—I have just returned from a business trip to America in connection with Radio, and naturally met a number of the leading Radio enthusiasts in U.S.A. This morning I have received a letter from Mr. E. T. Flewelling, whom no doubt your readers are fully aware is the inventor of the famous Flewelling Super-Regenerative Circuit.

He wishes to know if any amateurs on this side would listen-in for his station, 9XBG (Chicago, Ill.) on a wave-length of 70 metres, as he is confident he can get his signals over to this side, it being only necessary to have a prearranged time for working.

If any amateurs interested would care to communicate with me, I shall be very pleased to send Mr. Flewelling their names and addresses and also forward to them the times and dates arranged.

J. H. E.

c/o The General Radio Company, Ltd.,
6, Imperial Buildings,
Oxford Road,
Manchester.

The Numans Oscillator.

The Editor E.W & W.E.

SIR,—With reference to my article, "The Numans Oscillator," which appeared in your December number. In order to avoid any misunderstanding that might arise, I should like to emphasise the fact that the principle described does not depend upon the use of a double grid. Theoretically a correctly-proportioned valve with a single grid should function with equal efficiency. In practice, however, one seldom is fortunate enough to find such a valve, and, as a result, experimenters who adhere to the single grid type must be prepared to overcome various difficulties in adjustment and also, in the case of *some* valves, for complete failure to obtain satisfactory results.

The Hague. K. C. VAN RYN.

Low Power Tests.

The Editor, E.W. & W.E.

SIR,—I have read your criticism concerning the radio tests recently carried out by me on the R.M.S. *Tahiti*.

You are quite right in suggesting that of the figures shown something seemed doubtful. The radiation of the small transmitter should have read ·8 amps., instead of 1·8. The input power, however, is absolutely correct, as this was very carefully measured by the Amalgamated Wireless Co. with their own instruments.

With this radiation and an aerial resistance of 7·5 ohms at 235 metres the power in the aerial would be 4·8 watts.

CHAS. MACLURCAN
Sydney. (Radio A2CM.)

Esperanto.

Translation.

The Editor, E.W. & W.E.

SIR,—I have read with great interest the short course in Esperanto published in the December issue of your journal.

This publication comes most happily at the moment, when although wireless telephony is making the voices of all people heard beyond their frontiers, these voices are too often without useful effect, since they cannot be understood; and it is also especially appropriate since the first International Wireless Congress is about to bring together at Paris amateurs from all the world over, who will certainly have some difficulty in understanding one another.

I hope that your journal will not be content with what it has already accomplished, and that it will continue to assist the movement which is trying to propagate the use of Esperanto among amateurs and other users of wireless telegraphy and telephony.

DR. PIERRE CORRET,
Vice-President of the Société Française de l'Etude de Télégraphie et de Téléphonie sans Fil.
Vice-President of the Organisation Committee of the First International Congress on Wireless Telegraphy.

Versailles.

Translation.

The Editor, E.W. & W.E.

SIR,—Allow me to congratulate you most sincerely on your enterprise in inserting in your journal such a complete exposition of the grammar and principles of Esperanto.

You have shown very clearly the reasons which should lead a large number of wireless enthusiasts to make use of an auxiliary international language, and your article will make it possible for all readers to understand fully the exceptional ease of learning Esperanto, and will consequently make them appreciate the advantages which they may obtain by studying it.

Might I draw your attention to one aspect of the question which was not dealt with in the article in question, and which seems to me likely to interest many of the readers of a journal which, like yours, devotes itself to the technical and scientific side of wireless? It might be noted that this point applies not only to wireless, but to all scientific and other activities.

Periodicals of all kinds are becoming daily more

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numerous and more widely spread. They are written in so many different languages that the study of them is impossible for many, and very troublesome for all.

Further, as regards wireless, many very expensive publications, such as *The Philosophical Magazine, The Proceedings of the Royal Society, The Electrician, Journal of the Institute of Electrical Engineers* (to give only a few examples of English publications), contain from time to time articles of the greatest interest; but to obtain them all for the sake of their occasional interesting contents would cost a small fortune. In spite of every effort, it is becoming impossible to keep oneself completely abreast of current progress, and the position is becoming worse; specialisation is rapidly becoming indispensable, and the time which one is able to devote to the study of foreign languages is getting less.

The adoption of an international auxiliary language would be an effective remedy for this situation. It would abolish the very considerable effort necessary to learn existing languages, and it would allow—by reason of the larger number of readers—publication at a cheaper price of technical journals adapted for the needs of the whole world.

Sooner or later this change will come, but as it is already of real necessity, it is most important that all those interested in scientific matters, or even simply in progress, should make a personal effort to hasten it.

RÉNÉ MESNY,
Officier de Marine Attaché au Laboratoire de la Radiotélégraphie Militaire.

Paris.

Soldering.

The Editor, E.W. & W.E.

SIR,—I have read quite a lot of correspondence in various papers recently about soldering, but nothing about a good way of reaching difficult places.

In a medium sized iron I have screwed three inches of 2B.A. clearance rod (copper) the end of which is rounded off.

The iron is heated in the usual manner and tinned, including the extension, owing to the heat escaping through the least resistance the extreme end of the rod receives all the heat, and what is usually a ticklish job, becomes easy, especially for getting at connections of multi circuits.

Bournemouth. J. P. J. CHAPMAN.

International Radio Week.

THE full official reports of the results obtained during the International Radio Week are not yet available, but there is no doubt that when all the information from the logs of serious observers is collated, a mass of valuable data will be compiled that will afford a useful basis for similar experiments in future. The transmissions excited widespread interest, and, although some reports require more complete verification, there is no doubt that, on the whole, the results were sufficiently successful to justify the efforts.

An interesting feature was the great interest shown by the lay Press in the progress of wireless in general and broadcasting in particular. Practically every daily paper in Britain gave a column or more to reports from correspondents in Europe and America telling of good or indifferent reception. The latter country seems to have been the chief focus of attention, and KDKA (Pittsburg) to have been the principal centre of interest.

The full story of the romance of wireless yet remains to be told, but one event, at least, must make a direct appeal to every Londoner. For the first time, the solemn chimes of Big Ben were broadcast to the world, and thousands of people in many countries were able to hear the actual sound of the great bells that hitherto have meant nothing more than a name to them. It is also interesting to reflect that, owing to the enormous speed of electro-magnetic radiation, the chimes were heard in Pittsburg before they could be heard by an observer standing at the foot of the clock tower.

The Wireless Retailers' Association and the B.B.C. are chiefly entitled to credit for arranging the Radio Week. It was thoroughly international in character, and all countries, from South America to Northern and Central Europe, took part in it. This is only a beginning, and it may well be that broadcasting in the future will prove itself to be a greater influence in promoting good feeling among the peoples of the world and a better mutual understanding than has yet been accomplished by diplomatists or politicians.

Correction.

Owing to a mistake for which we were not responsible the price of Messrs. Mullard's valves as advertised in our December issue was given as 25/- for the types D3 and D.06, H.F. and L.F. valves. They now inform us that the price of the D.3 is 21/- and that of the D.06 25/-.

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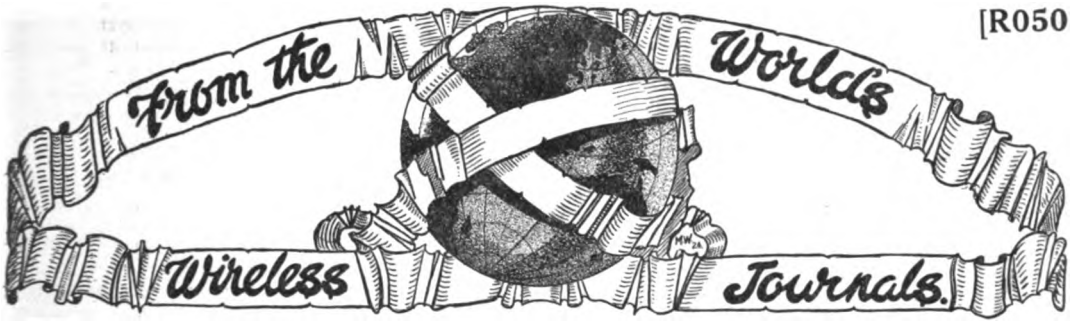
[R050



R100.—GENERAL PRINCIPLES AND THEORY.

R113·3.—Relèvements Radiogoniométriques à Changha.—E. Gherzi, S. J. (*Onde Elec.*, Nov., 1924).

Some observations made at Shanghai on the direction of arrival of radio signals from various long-wave stations of the world.

R113·6.—Why Wireless Electric Rays Can Bend Round the Earth.—Sir Joseph Harmor, F.R.S. (*Phil. Mag.*, Dec., 1924).

A theoretical discussion of the process by which electromagnetic waves may be caused to follow the curvature of the earth. The simple dispersion of waves emitted from a point on the surface of a sphere would not give rise to the observed amount of bending. The effect of the upper ionised atmosphere of the earth is therefore taken into account.

R125·1.—Etude d'un Cas Particulier d'Effet Antenne sur un Cadre de Radiogoniometre.—B. Hyot (*Onde Elec.*, Nov., 1924.)

A study of the combination of the electrostatic and electromagnetic pick-up effects of a frame aerial to give a "heartshape" polar reception curve.

R131.—An Indirect Method of Determining the Grid Characteristic.—M. E. Janmoulle, B.Sc. (*W. World*, Nov. 19, 1924).

A simple method, requiring only easily-procurable apparatus, of plotting the grid-volts, grid-current curve of a valve.

R134.—Cumulative Grid and Anode Current Rectification.—H. J. Barton Chapple, Wh.Sch., B.Sc.(Hons.) (*Exp. W.*, Dec., 1924).

Results of some quantitative tests, showing the degree of rectification obtained with various values of grid resistance, grid and anode voltages.

R138.—L'Influence de la Température sur les Tubes Thermioniques.—M. Courtines (*Onde Elec.*, Nov., 1924.)

A study in anomalies in emission found in thermionic valves. It has been found that emission of a filament supplied with a constant heating power does not remain constant, but may fall off appreciably within the period of half an hour or even a few minutes.

R141.—The Graphical Analysis of Composite Impedances.—F. M. Colebrook (*Exp. W.*, Dec., 1924).

In this paper the author considers some of the important arrangements of impedances met with in practical wireless work, and shows their characteristics graphically.

R144.—Effective Resistance.—M. G. Scroggie, B.Sc. (*Exp. W.*, Dec., 1924).

This article deals with sources of loss which can often be considered as if produced by a resistance.

R200.—MEASUREMENTS AND STANDARDISATION.

R250.—Measurement of Aerial Current.—N. W. McLachlan, D.Sc. (*W. World*, Dec. 3, 1924).

The method described involves the use of a low reading H.F. ammeter in conjunction with an iron cored current transformer.

R251·2.—Sur les Precautions qu'il Convient de Prendre dans l'Utilisation des Thermocouples à Fils Croisés en Radiotechnique—J. Cayrel (*Onde Elec.*, Nov., 1924).

Note on precautions to observe when using thermocouples of the crossed-wire type.

R300.—APPARATUS AND EQUIPMENT.

R342·7.—The Perfect Set. Part III.: L.F. Amplification.—(*Exp. W.*, Dec., 1924.)

The article states clearly the fundamental working conditions and the requisite adjustments for a three-electrode valve working as a low-frequency amplifier.

R343.—A Receiver for Wave-lengths of 3 to 5 Metres.—E. H. Robinson (*Exp. W.*, Dec., 1924.)

Description of a simple and robust regenerative receiver for ultra-short radio waves.

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R344.—THE NUMANS OSCILLATOR.—K. C. van Ryn (*Exp. W.*, Nov., 1924.)

Description of a new valve oscillatory circuit, which requires only one tuned circuit without any extra tappings or reaction coil.

R351.—GENERATEUR-AMPLIFICATEUR SANS LAMPE. —O. Lossev (*R. Elec.*, Nov. 10, 1924.)

An original article dealing with the practical use of crystal contacts for generating oscillations and producing amplification.

R375·2.—LES PHÉNOMÈNES ELECTROSTATIQUES DANS LES DÉTECTEURS A LIMAILLE ET À CONTACTS IMPARFAITS.—Joseph Waszik (*Onde Elec.*, Nov., 1924.)

Description of some experiments made to ascertain some of the electrical properties of coherers and loose-contact detectors.

R382·1.—SHORT-CIRCUITED TURNS AS AN AID TO RECEPTION ON SHORT WAVES.—W. E. Benham (*Exp. W.*, Dec., 1924.)

By short-circuiting a few turns in the reaction coil of a short-wave receiver it has been found possible to increase the effective mutual coupling to the grid circuit without bringing the reaction coil above resonance.

R382·5.—SUPERHETERODYNE TRANSFORMERS.—(*Q.S.T.*, Dec., 1924.)

An article discussing the construction and desirable properties for "intermediate frequency" transformers in supersonic heterodyne receivers. Frequency-amplification characteristics of iron and air-cored and iron-cored intervalve transformers respectively. The undesirability of excessively sharp resonance in such transformers is explained.

R385·52.—THE MARCONI-SYKES MAGNETOPHONE.—H. J. Round, M.I.E.E. (*W. World*, Nov. 26, 1924.)

A detailed description of the Sykes microphone and its associated amplifying circuits as used in British Broadcasting Stations.

R600.—STATIONS: DESIGN, OPERATION AND MANAGEMENT.

R620·068.—FAULT TRACING.—L. R. Gleason (*Exp. W.*, Dec., 1924.)

Methods of diagnosing defects without measuring instruments.

R800.—NON-RADIO SUBJECTS.

R800.—A SHORT COURSE OF ESPERANTO, THE INTERNATIONAL LANGUAGE (*Exp. W.*, Dec., 1924.)

An introduction to the grammar, vocabulary and pronunciation of Esperanto, especially arranged to be of immediate use to the radio experimenter.

R800.—ELECTRON EMISSION FROM ADSORBED FILMS ON TUNGSTEN.—K. H. Kingdom (*Phys. Rev.*, Nov., 1924.)

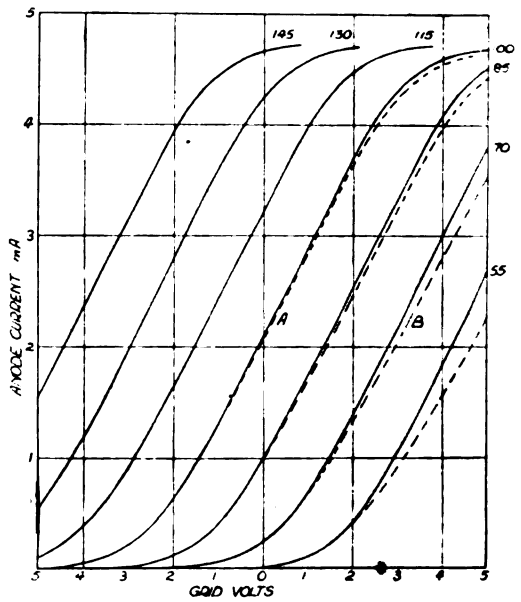
Some experimentally-determined data showing how the constants of the Richardson emission formula are affected by the presence of layers of certain substances on tungsten filaments, particularly oxygen, nitrogen, caesium and thorium.

More about Valve Testing.

Two errors of a rather serious nature occurred in the article under the above heading in last month's issue.

On page 180, by a printer's error, the number 80 appeared instead of 70 for the anode voltage for which the curve B in Fig. 2 was plotted.

Moreover, through circumstances beyond our control, a block from an entirely different article was published as Fig. 2. The correct set of curves is given herewith.



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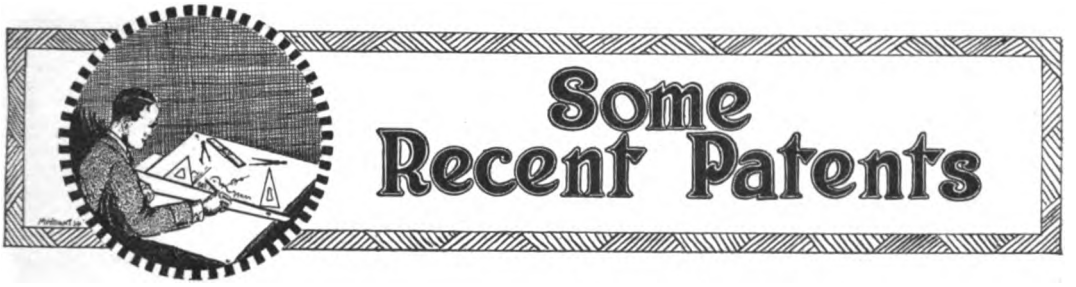
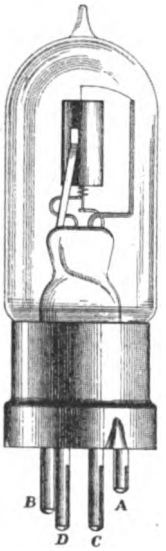


(The following notes are based on information supplied by Mr. Eric Potter Patent Agent, Lonsdale Chambers, 27, Chancery Lane, W.C.2.)

[R008

VALVE PROTECTION.

THE Edison-Swan Electric Co., Ltd., and T.C. Black, described in British Patent No. 220498, Application Date, October 10, 1923, the construction of a valve which cannot be damaged by momentary incorrect insertion in a valve holder. Should an attempt be made to insert an ordinary valve in the incorrect sockets it frequently happens that almost the full voltage of the high tension battery is applied to the filament. This eventuality is obviated by the special construction shown in the accompanying illustration. It will be noticed that two of the valve legs, A and B, are of dissimilar length, and each is shorter than the other two, which are of normal dimensions. The two special legs correspond to the ends of the filament while the ordinary ones are connected respectively to the grid and anode, shown at C and D. It will be apparent that it is absolutely impossible for the filament to be connected across the high tension supply, however the valve may be held above the holder. We should imagine that the device would not be so protective in the case of a valve-holder consisting of long, exposed brass legs, as experience shows that it is quite easy to place a valve amongst the sockets without any of the legs entering them.

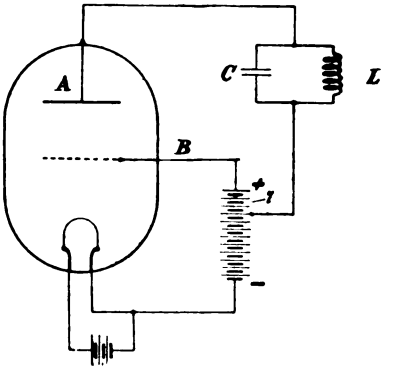


AN IMPROVED ELECTROLYTIC CONDENSER

British Patent No. 216,139, Convention Date, May 14, 1923 granted to A. Soulier, claims that the functioning of an electrolytic condenser can be materially improved by the use of picric acid or trinitrophenol, preferably mixed with an alkaline base such as caustic soda. The invention also claims the addition of a tartrate, citrate, or borate which allows the use of a higher voltage.

A MODIFICATION OF THE DYNATRON.

Some very interesting details are disclosed in British Patent No. 214,262, Convention Date, April 11, 1923, granted to the N. V. Philips Gloeilampenfabrieken Co., and relate to a valve generator operating on the dynatron principle. The accompanying illustration shows a normal dynatron circuit which, of course, operates by virtue of secondary emission. The inner electrode B is made more positive than the external electrode or anode A. The inner electrode is of grid formation and owing to its high positive potential with respect to the filament, primary electrons from the filament pass through it at very high speeds impinging on the surface of the anode A. The velocity of the electrons at impact is sufficient to cause secondary electrons to be knocked out of the anode which then go towards the grid. One primary electron will dislodge several secondary electrons and consequently the characteristic of the grid anode circuit is falling, or shows a negative resistance effect. Hence if an oscillatory circuit is included in the anode circuit as at LC, oscillations will be set up at a frequency depending upon the constants of that circuit. This process is materially improved according to this invention, by utilising a rather different construction for the anode, and is intimately connected with the Richardson constant of the material of which the electrode is composed. The Richardson constant of a material is merely a measure of the quantity of work required to dislodge an electron from the surface of any given substance. Metals, such as tungsten, have been previously employed for the electrode of which the constant has been of the order of 4·5. This invention claims the use of materials of which the constant is smaller than 3, such as the alkali-metals or their oxides. Accordingly the electrode may be coated in a somewhat similar manner to the dull-emitter filament. It is therefore obvious that the use of an electrode of the coated type just described gives a very greatly increased efficiency.



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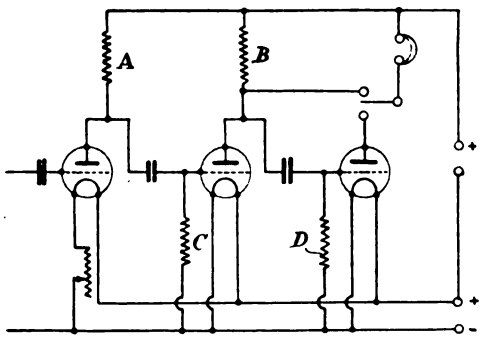
A PECULIAR RESISTANCE AMPLIFIER.

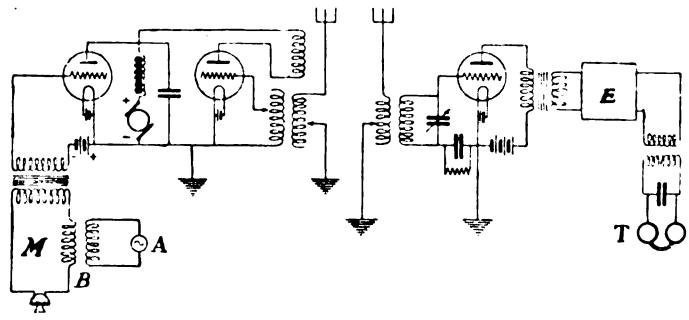
H. Lloyd, E. B. Homer and A. Dilger have been granted British Patent No. 220,488, Application Date, September 28, 1923, for a rather peculiar form of resistance-coupled amplifier. The circuit is shown in the accompanying figure and is, of course, quite normal, the invention lying in the particular values chosen for the resistances. The object of the invention is to cause the first valve to operate as a detector-amplifier and the subsequent valves as amplifiers. The scheme is said to be operative with R type valves using a high



tension battery of 60 to 100 volts, thereby dispensing with the extra large battery usually required for resistance-amplifiers. The first peculiar feature is the value of the anode resistance A in the anode circuit of the detector valve which is as high as 5 megohms. This anode is capacity coupled to the grid of the first amplifier which has a grid-leak as high as 20 megohms. The anode resistance B in the anode circuit of the second valve is also very high, of the order of 3 megohms, while the last grid-leak D is from 10-15 megohms. It is stated that owing to the values chosen the first two valves operate on the bottom bend of the characteristic, while the third valve operates on the straight portion of the characteristic. Further, it is stated that the first valve operates as a detector while the second operates as an amplifier. A characteristic curve for the first two valves is shown without any values of anode current and grid volts and is identical in shape with the ordinary static characteristic for an R type valve without any load in the anode circuit. It would be very interesting to take the characteristic of an R valve with an anode battery voltage of 60 volts and a series resistance of 5 000 000 ohms.

SECRET TELEPHONY.

"Narrowcast Transmission" appears to be the latest addition to our radio vocabulary according to British Patent No. 198,368, Convention Date, May 26, 1922, owned by the Marconi Co., Ltd. The idea of the invention is to provide a transmission which can only be received by authorised stations. The scheme is illustrated by the accompanying figure. The object of the arrangement is to introduce undesired frequencies into the modulation, and then to remove them at the receiving end, so that to any but an authorised receiving station the transmission would be absolutely unintelligible. Referring to the figure, the apparatus on the left represents an ordinary choke control telephony transmitter, while that on the right represents an ordinary receiver. In the modulation circuit M of the transmitter, there is included an auxiliary modulator A, which is coupled to the normal circuit by the transformer B. The auxiliary modulator is in constant operation, and the speech or music frequencies are imposed upon the steady modulation. Between the telephones and the anode circuit of the last valve of the receiver it will be seen that there is a device E which is merely some form of filter, tuned to cut out the frequency supplied by the auxiliary modulator. The frequency of the steady modulation has to be chosen with great care so as not to render successful filtering difficult. The specification states that the best frequencies to employ are those below about 30 cycles per second, or above 2 500, *i.e.*, outside the normal speech range. Other arrangements provide for the less important frequencies within the speech range, and also sets of tones which will give a discordant resultant, together with combinations and variations of the above. The filtering devices used in the receivers are essentially high and low pass filters or band pass filters. In practice, the filter element is set in cement so as to render the operation of investiga-



tion and duplication exceedingly difficult by any unauthorised person. One can picture the day when the receipt for a yearly broadcast licence takes the form of a band pass filter set in cement, which automatically burns out after twelve months' use.

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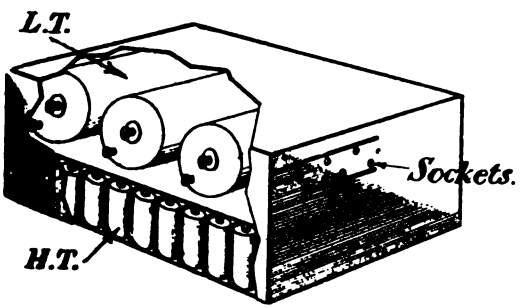
MODIFICATION OF THE LUMIÈRE DIAPHRAGM.

The Société des Establisements Gaumont in British Patent No. 210,405, Convention Date, January 27, 1923, give some constructional details of a modification of the well-known pleated diaphragm type of loud-speaker originally developed by Lumière. The loud-speaker, it will be remembered, consists essentially of a large pleated diaphragm supported at its periphery by a heavy ring. It is now proposed to add a diametric cross member to which can be attached a microphone or hand receiver. Various modifications and combinations are described and it would appear that the arrangement is primarily intended for office use.

A BATTERY PATENT.

The Marconi Co., Ltd., in British Patent 209,740, Convention Date, January 9, 1923, give details of the construction of a self-contained power unit suitable for supplying current to a broadcast receiver. The invention really consists in placing in one box the high and low tension batteries and so proportioning the size of the cells that they all cease to function at substantially the same time.



Larger cells are therefore used for the power stages than for the amplifiers and detector. The first claim of the patent is extremely broad and covers the use of a single power unit comprising filament and anode batteries together with a plug and socket device for simultaneous connection to the associated receiver. The use of separate anode and filament batteries mounted in one box with a plug connection has been used, we believe, for some considerable time and would not appear to be covered by this patent.

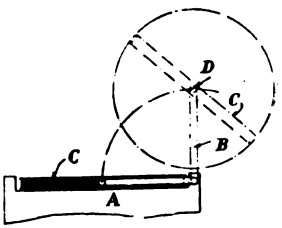
CRYSTAL DETECTOR.

(Application date, July 5, 1923.)

The crystal detector described in British Patent 217,066 of Messrs. H. H. Parkin, G. Parkin, W. Parkin and F. Parkin and already on sale as the "Climax," is characterised by the simplicity of the crystal mounting. Instead of being held in the usual cup the crystal is gripped between the jaws of a spring clip. A firm contact with the crystal is thus secured, while at the same time an interchange of crystals can very readily be effected or the disposition of the same crystal may be varied to bring any desired part of its surface in contact with the cat-whisker.

A FRAME AERIAL CABINET.

E. A. Graham claims in British Patent No. 220,352, Application Date, April 18, 1923, the use of a frame aerial associated with a cabinet according to the following scheme: One side of the cabinet A in the accompanying illustration is recessed and is provided with two movable arms, one of which is shown at B. The frame aerial C is pivoted at D at the ends of the arms and may thus be turned about a vertical axis through 360 degrees. An alternative arrangement, which is preferable from an electrical point of view, provides for the use of extensible arms B and therefore enables the frame to be swung out farther into space and is not so liable to be affected by the presence of the apparatus within the cabinet. The frame aerial when not in use folds away into the side of the cabinet as shown in the illustration.

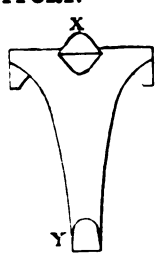


AN INTERNALLY COUPLED VALVE.

A rather peculiar valve is described in British Patent No. 220,388, Application Date, May 17, 1923, granted to J. Robinson and W. H. Derriman. The object of the invention appears to be to provide a receiver which is as light and compact as possible. This is accomplished by eliminating the coupling coils between the anode and grid circuits. The coupling is obtained between the actual grid and anode of the valve which are made in spiral formation and arranged concentrically. Both ends of the anode and grid spirals are, of course, provided with terminals. A modification of the invention provides for additional magnetic coupling within the valve by the provision of auxiliary inductances arranged round the anode. Fine adjustment of the coupling is arranged externally in the ordinary manner, either electro-magnetically or electro-statically.

AN INDOOR AERIAL SUPPORT.

An ingenious aerial support is described in British Patent No. 220,459, Application Date, August 10, 1923, by R. B. Gill. It will be seen from the accompanying illustration that it consists essentially of an ordinary picture hook with an additional lug X bent upwards at the top. The weight of the picture hanging from Y keeps the device rigidly in position, while the aerial wire is hooked round the projecting lug.



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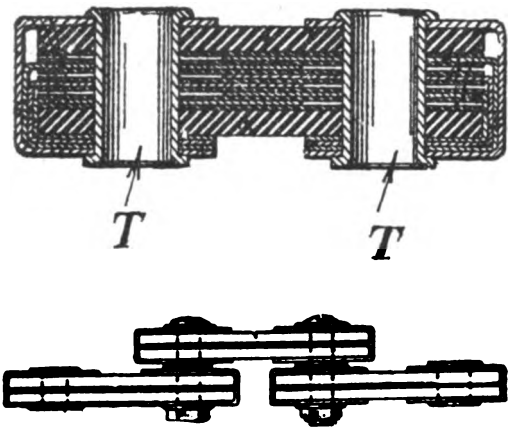
CONDENSER CONSTRUCTION.

W. Dubilier has been granted British Patent No. 198,362, Convention Date, May 23, 1922, for a method of condenser construction which is



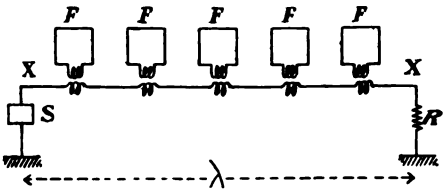
illustrated by the accompanying drawing. It will be seen that the elements of the condenser are clamped together by means of hollow tubes, T, the ends of which are riveted over. This type of construction enables the condenser to be connected in series for high voltage work merely by passing bolts through the tubes, as shown in the lower half of the illustration.

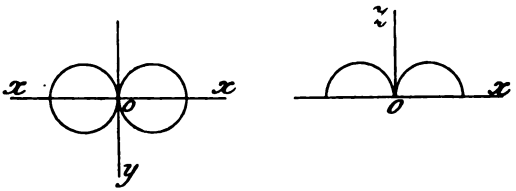
THE "POLAR BLOK" PATENT.

The well-known " Polar " unit system is described in British Patent No. 220,354, Application date May 2, 1923, and is due to R. Ferguson and R. E. Beswick and the Radio Communication Co., Ltd. The system is no doubt too well known to need lengthy description, and the essence of the invention is probably best summarised by quoting the first claim which reads as follows: "An extensible frame for a sectional panel board, wherein the frame members and junction pieces are secured in the assembled position by a spring or snap locking connection which also definitely positions the co-operating elements with respect to each other."

AN IMPROVED BEVERAGE AERIAL.

Le Société Française Radio-Eléctrique describe in British Patent No. 215,014, Convention Date, April 26, 1923, an improved form of Beverage aerial. It has been found that when the ground beneath the aerial is a very good conductor, the directive property of each element of the conductor is affected and maximum radiation is likely to occur towards the zenith. This defect is obviated by the scheme shown in the accompanying illustration, in which a number of frames are combined with each element. The aerial, which is one wavelength long is shown at XX, while S denotes the receiver and R the non-reflection resistance. The whole aerial is divided, for example, into five sections or elements each of which is coupled to a frame F. Considering each element separately it





is seen that it will have no radiation in the direction of the zenith, while radiation in the direction of the conductor will be a maximum, which therefore results in a more efficient arrangement.

STANDARDS ASSOCIATION.

The Main Committee of the British Engineering Standards Association have recently authorised the Secretary, Mr. le Maistre, to accept the cordial invitation of the German Standards Committee (the N.D.I.) to be present at their annual meeting on December 13th. He is also going to Prague to give an address on Industrial Standardisation before the recently-formed Czechoslovakian Standards Committee.

2KK.

The above call sign, originally the property of a London transmitter, is now owned by Mr. Ralph H. Parker, Wilson Road, Smethwick, Staffs. 2KK welcomes reports of transmissions on short waves.

THE ROMAN STATION.

The Marconi Company advise us that the call letters allotted officially to the Broadcasting Station at Rome are 1RO.

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EXPERIMENTAL WIRELESS & The WIRELESS ENGINEER

VOL. II. FEBRUARY, 1925. No. 17.

Editorial Views.

Valve Capacities.

WE are sure that our readers will be deeply interested in the article by Messrs. Hartshorn & Jones, giving the results of tests at the N.P.L. on the capacities of valves (p. 263), not only because (in conjunction with Mr. Chapple's article last month and Mr. White's letter in our correspondence columns) it gives valuable information on a point as to which published data are scanty, but also because of the very interesting account of the method of measuring small capacities, and the many points to be allowed for in finding a true capacity independent of earth effects.

This article has great educative value for all experimenters in showing how tricky it is to make accurate measurements. Whereas quantitative work of an approximate nature is easy and extraordinarily fascinating, accurate work—just as fascinating—is most difficult. When new types of measurement are being done, it really requires a special sort of genius which smells out hitherto unguessed sources of error.

With regard to the particular subject of this article, we should like to emphasise very strongly the point made by Mr. Hartshorn, that the capacity of a valve as measured in this way is by no means the same thing as its apparent capacity when working. This point was strongly brought out in the paper by Miller referred to by Mr. Hartshorn, and we have long been anxious to apply Miller's equations to British valves under ordinary working conditions. Now that we have definite data to work on (for the effective capacity is a function of the measured capacity) we already have this in hand, and we hope to have the results available in the near future.

Readers' Suggestions.

From time to time we receive from readers suggestions as to articles which they would like to see in E.W. & W.E.—incidentally, we should like to say that we welcome such suggestions, and would like even more of them. Sometimes the suggestions are such that we can accept them or refuse them without difficulty. Often, however, we find it hard to decide whether such articles would really fill a need or not.

We have in mind two recent suggestions. One of these is for a series of articles dealing in a simple way with circuit calculations, beginning right at the beginning. Such articles, if they are to be easy to read (and yet give accurate information) are difficult to write; but we shall be glad to have them written if they are called for.

Another suggestion is for articles in the setting up and use of a "wireless laboratory," *i.e.*, first, what instruments *must* be bought; how to calibrate home made standards from these, and how, finally, to conduct measurement work.

We shall be glad to hear from any readers who have decided views for or against the inclusion of such articles.

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International Language.

Among our correspondence in this issue is a letter on the subject of international language. The writer of this letter is a believer in a language called "Ido," and a considerable portion of his letter was devoted to pointing out in detail some matters in which he claims that Ido is a better language than Esperanto.

We have taken the rather unusual step of cutting out this part of his letter, and we feel that some explanation of this is due to our readers.

The point is that E.W. & W.E. is not a philological paper; it is a wireless paper, and the study of an international language has been recommended for wireless purposes. We chose Esperanto from among the various international languages because the largest national wireless amateur organisation (the A.R.R.L. of America) had already done so, and because the forthcoming international wireless congress at Paris is doing so.

When the A.R.R.L. made their decision, they refused to pronounce on the comparative merits of various languages. They said, very sensibly, that this was not their job. They decided on Esperanto because it is already the most used (we believe we are safe in saying that at a conservative estimate there are about ten times as many users of Esperanto as of all others), and therefore the most useful, and we agree with their point of view.

We have seen in other wireless papers some very bitter discussions of the comparative merits of this or that language, and we believe that our readers will support us in saying that such discussions shall have no place in the columns of E.W. & W.E. In fairness, however, we are prepared to insert one reply from an Esperantist to the letter in this issue.

Calibration.

As will be seen from p. 276, the E.W. & W.E. calibration department is now again open, but under new conditions.

We trust that our readers will approve of these conditions, which are in essence that (apart from present subscribers, who are specially dealt with) the service is now open to all readers at a fee instead of gratis and confined to subscribers. There are many reasons why the restriction of the service to subscribers was unsatisfactory. It was originally adopted mainly to discourage a large number of casual readers who, when the department was first opened, sent in large quantities of apparatus of indifferent quality.

To be perfectly frank, the fees now to be charged are designed largely with this same object. We are prepared, within limits, to calibrate anything, but the calibration of badly made components is largely wasted labour, and we feel that the payment of a fee will help to bring home to readers that if it is worth while having something calibrated it is worth while making a sound job of its construction.

From the inquiries received while the department was closed, we suspect that there may be a rush of apparatus now that it is re-opened. In case this should occasion any delay in the work, we should like to state that instruments are taken in rotation as they arrive, and that it is useless to offer extra payment in the attempt to influence our testing staff to make exceptions. We should have thought it hardly necessary to make such a statement were it not for actual experience during the last few months.

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The Arrangement of Wireless Books and Information.

Part V: R400 and R500. [R025·4

These two sections are not divided into such detail as the previous ones, which has enabled us to find room for both of them in one issue.,

R400 Systems of Working.

This section is devoted to description of the essential features of wireless communication systems *as systems*, as apart from the theory or practice of instruments used. There may at first be some difficulty in allotting some matter correctly: the only method is to look into the point of view of the article or book.

Just as an example, take the subject of self-heterodyne working. Matter dealing with the generation of local oscillations by a valve, as such, goes in R133; the combination of detection and self-oscillation in R134·7; and the design of receivers of this type in R343·4. But a description of the action of two H.F. currents in producing beats is of the essence of the system itself, and should be placed in R426. Remember that descriptions of stations (except when given simply to illustrate a system), are dealt with under R600. We shall insert cross-references to the other sections.

In the original B.S. Extension there are two headings,

R402 High power,
R401 Short wave,

which, as in other cases already mentioned, might clash with the form division. We therefore suggest that they be not used. Where it is necessary to make a distinction between stations of varying power and wave, we suggest a special subdivision of 012, which reference to the form division will show to be "classification and special branches," as follows:—

R401·2	Systems: classification and special branches.
·21	Special points in and systems for extra high power work.
·22	Simple systems for low power.
·23	Special arrangements, etc., for extra long waves.
·24	Special arrangements, etc., for extra short waves.

The figures 0121 to 0124 will be applicable to any subdivision of R400, *e.g.*, R412·0123, long-wave telephony.

R410 Modulated-wave systems.

R411	Spark systems.
R411·2	Quenched spark.
·4	Rotary gaps, synchronous.
·6	Rotary gaps, asynchronous.
·9	Other spark systems.

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R412 Telephony systems. (See also R135 and R345.)
R413 L.F. modulated systems (*i.e.*, tonic train, etc.)
R414 H.F. modulated systems. (See also R460, multiplex, etc.; also secret systems, R435, which often depend on H.F. modulation.)

R420 Continuous-wave systems.

R421 H.F. alternators. (See also R154 and R354.)
*R421·1 Fessenden and Alexanderson direct H.F. alternators.
* ·2 Goldschmidt alternators.
* ·3 Separate frequency-raiser systems. (See also R357.)
R422 Arc systems (See also R153 and R353.)
R422·1 Spacing waves.
R423 Valve systems.
This entry must be used with care. Most valve matters are better dealt with under R130 or R340.
R424 Timed spark systems.
R425 Impulse excitation.
R426 Beat reception. (See also R134·7 and R343·5.)
R427 Tikkers, tone wheels, etc.
R429 Other methods of receiving C.W.

R430 Interference elimination. (See also R162.)

R431 Eliminating atmospherics. (For data on atmospherics, see R114.)
R432 Avoiding interference from other stations.
*R432·1 Rejectors, wave-traps, etc.
R435 Secret systems.

R440 Remote control of wireless stations.
R450 Linkage, relaying, etc.
R460 Duplex and multiplex systems.
R470 "Wired wireless."
R480 Recording and relay-operating systems.
R485 High-speed working.
R487 Printing systems.

R490 Other systems.

R492 Buzzer sets.
R493 The Fullerphone.
R495 "Tree Telegraphy."

R500 Applications and Uses of Wireless.

This important section will, like R400, contain matter treating of subjects which have often been dealt with in R100 or R300; again, like R400, the criterion is the *point of view* or *object* with which the matter was written, for which its preservation is desired.

R510 Navigation.

Do not confuse this with "ship traffic," which is essentially a commercial service. It is curious that in the B.S. Extension there appears to be no special subsection for ship traffic as distinct from general commercial traffic. We take it, however, that it is intended to deal with it under 531, and have done so. R510, therefore, will be devoted to navigation work, apart from broadcast reports on navigation subjects, which come under R550.

*** These subdivisions are proposed by us as a tentative further extension.**

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R511	Distress signals.
R512	Radio beacons, *i.e.*, land stations for ship D.F. work.
R513	Fog signalling by wireless.
R514	Radio compass, *i.e.*, ship stations for D.F. work.
R515	Submarine wireless.
R516	Life-saving service.

R520 Aircraft wireless.

R521	Aircraft reception.
R521·1	D.F. work.
·3	Magneto interference.
·5	Receiver helmets and fittings.
R522	Aircraft transmitters.
R522·3	Aircraft microphones.
R523	Reception from aircraft.
R524	Transmitting to aircraft.
*R524·1	Technical points.
·3	Local landing signals.
* ·5	Aircraft navigation work generally. (Divide like R510 if needed, *e.g.*, R524·51, Aircraft distress signals.)
R525	Aircraft aerials.

R530 Commercial and allied services.

R531	Traffic. Note that the actual *handling* of traffic will mostly be dealt with either under technical headings or under R620, station operation and management. But there are many points to do with wireless services which are not exactly station management, and these are grouped here.
R531·1	Codes and ciphers (for abbreviation and secrecy: not the Morse code, which is dealt with under Alphabets.).
·15	Speed of code reception.
·2	Station call letters.
·3	Abbreviations.
* ·31	Official service abbreviations (" Q " calls).
* ·36	Service abbreviations.
·4	Alphabets.
* ·41	International Morse.
* ·42	American Morse.
* ·43	Special forms of Morse (Squier codes, etc.).
* ·49	Other alphabets.
·5	Coupling to land lines.
·6	Coupling to cables.
·7	Rates and charges.
* ·8	Special services (reply paid, delayed service, letter services, etc.).
R532	Press service (over commercial systems: special installations owned by the Press are under R540).
R533	Railway service work. (See note to R532.)
R534	Agricultural service. (This, we believe, refers to American Government services.)
R535	Forestry service. (See note to R534.)
R536	Wireless in mines.
R537	Wireless for long-distance power supplies.

R540 Private installations.

This covers both experimental (and broadcast reception) work and also private business installations, *e.g.*, for communication between separate branches of business firms (forbidden in the United Kingdom).

*** These subdivisions are proposed by us as a tentative further extension.**

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R541		Business installations, for inter-branch working. Installations for the reception of *broadcast* matter for business purposes (*e.g.*, market reports) come under R542.
R542		Broadcast reception.
R545		Amateur wireless work.
	*R545·1	Transmission.
	* ·6	Reception.
	* ·9	Special experimental work.

R550 Broadcast transmissions.

This is to be interpreted in the wide sense of the word, and includes all matter intended for reception by anyone, as distinct from messages to a specific addressee.

R551		Time signals.
	R551·1	Longitude determination.
*R552		U R S I and similar signals for the measurement of attenuation, etc.
R553		Meteorological signals.
*R554		Signals for mariners: sea weather reports, gale warnings, etc.
R555		Calibration waves.
R556		Market reports.
*R557		" Entertainment " broadcasting.

This must obviously be the subject of a considerable extension at an early date. It is, however, too large a matter to undertake at the moment. For the present, we suggest the use of the form division.

R560 War service wireless.

R561	Military.
R565	Naval.
*R568	Air service.

R570 Distant control by wireless.

R580 Sundry applications :—

R581	Wireless power transmission.
R582	Transmission of pictures, etc.
R583	Radio-therapy (*i.e.*, medical applications).
R584	High-frequency furnaces.
R585	Wireless toys.
*R586	Television.

R590 National Developments.

This is rather hard to distinguish from history. It is probably best to keep the history of detail subjects (*e.g.*, valves, or aviation work) under its own heading, with the form divisions R090·1 to R090·9, while keeping the general history of development by countries in this section. It will be noted that the territorial division is the same in both cases.

R591		Wireless in the U.S.A.
R592		British Empire.
	592·2	United Kingdom.
R593		France.
R594		Germany.
R595		Italy, Spain, Portugal.
R596		Norway, Sweden, Denmark.
R597		Asia, Africa.
R598		S. America.
R599		Elsewhere.

*** These subdivisions are proposed by us as a tentative further extension.**

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The Inter-Electrode Capacities of Thermionic Valves. [R220 : R333 : R382·8

By L. Hartshorn, A.R.C.S., D.I.C., B.Sc., and
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The Authors draw attention in this paper to the importance, in some instances, of the frequently-ignored capacities between the grid and filament of valves. The method of measurement is particularly interesting.

The Importance of Valve Capacities.

THE capacities between the electrodes of a valve are known to be very small (generally less than 10$\mu\mu$F), and thus for many purposes they may be neglected, but cases do arise in which these small capacities form the greater part of the capacity in a circuit, and thus a knowledge of their magnitude and power factor becomes of the greatest importance. Consider, for example, the input circuit of an amplifier. Here the capacity between the filament and grid of the valve forms a large part of the capacity in the circuit, and although this capacity is very small, it constitutes a load in the input circuit. The work of Miller, which will be referred to later, has shown that as a consequence of the capacity between the grid and anode, this capacity load in the input circuit may be considerably magnified, and further, that the effective power factor of this capacity load may be quite considerable, depending on the load on the anode circuit and probably to a still greater extent on dielectric losses in the valve. In such cases there will be a comparatively large loss of power in the input circuit and consequently a serious loss in efficiency of the amplifier.

Perhaps the most obvious case in which these small inter-electrode capacities play a leading part is that of circuits for the generation and reception of very high frequency radiation.

From an historical standpoint, it will be interesting to recall that Mr. W. C. White* in 1916 published an account of a method by which he succeeded in reaching a frequency of 50 million cycles per second. The attainment was of theoretical interest only since the amount of power that was rendered available was very limited and only served the lecture room purpose of demonstrating stationary electric waves of about six metres in length. For tuning the experimenter depended entirely upon the inter-electrode capacity of filament to grid and the inductance produced merely by the disposition of the leads in his circuit. Thus the inter-electrode capacity, on the one hand, and the least possible length of connecting wire and the area enclosed by it marked the limits of the frequency which he could hope to attain. For power purposes he was further handicapped by the inadequacy of the coupling between the filament-grid and the grid-anode circuits, as he had to rely entirely upon the capacity of anode to grid.

Work of a more applied nature was undertaken by Franklin,* Marconi,† and still later by Dunmore and Engel‡ of the Bureau of Standards. The work of the latter is particularly interesting as they give full working details of their circuits and appliances in their experiments with a wave-length of ten metres. Their generating arrangement was a Hartley circuit and consisted of a single turn 17 cm. (7 inches) in diameter for plate coupling and a similar coil for grid coupling. "With these coils the internal capacities between the elements of the valve formed the oscillatory circuit and determined the upper limit of frequency." At the receiving end, the coupling between the antenna and the receiving set consisted merely of two coils 1 foot in diameter in either circuit and

* White, *General Electric Review*, Vol. 19, 771, 1916.

* Franklin, *Wireless World and Radio Review*, Vol. 10, 219, 1922.

† Marconi, *Proc. Inst. Radio Engineers*, Vol. 10, 215, 1922.

‡ Dunmore and Engel, *Bureau of Standards*, Paper No. 469, 1923.

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could not be increased without, at the same time, rendering the capacity in the receiving circuit impossibly small to obtain or to vary for tuning purposes. The valve used for transmission was a 50-watt tube.

It is instructive to obtain a rough estimate of the amount of capacity permissible in the receiving circuit referred to. The coils mentioned would possess an inductance of the order of 1 microhenry. A wave-length of 10 metres represents a frequency

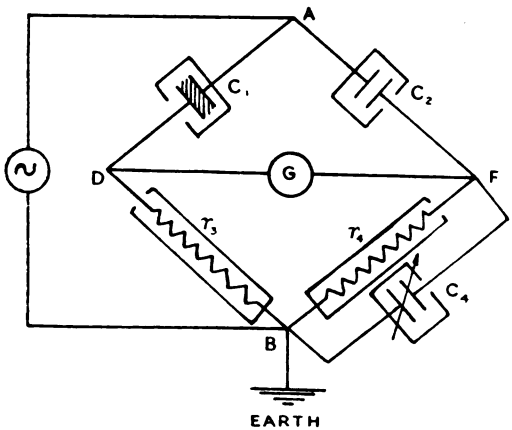


Fig. 1.

of 30 million cycles per second. From the relation $LC\omega^2=1$ we find that

$$C(\mu\mu F) = \frac{10^{12}\times 10^6}{4\pi^2\times 900\times 10^{12}} = 28.$$

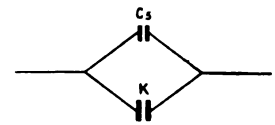
It will be seen on perusing the results given later in this paper that a frequency of about twice the value quoted above would be the utmost limit permitted in such a case if the ordinary type of valve were employed.

Other cases frequently occur in the course of general wireless experimental work in which an idea of the capacities between the electrodes of valves is of great importance. As there seemed to be no published information on this subject we decided to undertake a series of measurements on typical valves in order to obtain an idea of what the capacities are in any particular case, and what variation is likely to exist between valves of different types, between different samples of the same type and make, and between those of the same type, but different makes.

Method of Measurement.

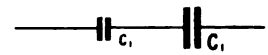
(*a*) *The Bridge.*

Before proceeding to give numerical examples, we shall describe very briefly the method employed. The essence of the method has already been published by one of us,* so that here we shall confine ourselves chiefly to the practical side. It is an adaptation of a more general form of alternating current bridge first described by Schering,† and subsequently used largely at the Physikalische Reichsanstalt. This is a particularly convenient bridge for Capacity and Power Factor measurements where good standard variable air condensers are available for comparative purposes. This arrangement is indicated in Fig. 1. Owing to the high impedance of the bridge the voltage can be pushed upwards until the necessary sensitivity is reached and is only limited by the insulation of the condensers employed. It is highly advisable to have the condensers and resistance arms screened and connected up in the bridge in the manner shown, as stray capacities of various members of the arms to earth are thereby definitely located and practically eliminated in their influence on the capacity to be measured. We make no apology for including a brief description of the Schering Bridge as we consider that it is by no means as well known in England as it deserves to be.



C

Fig. 2*a*.



K

Fig. 2*b*.

(*b*) *Vernier Capacity Standard.*

The adaptation of this bridge for small capacity measurements depends for its efficacy upon the usual relations connecting the capacities of condensers in series and in parallel.

In parallel $C=K+c_5$

In series $K=\frac{c_1.C_1}{c_1+C_1}$

Let us suppose that C (Fig. 2*a*) is the capacity of one arm of the bridge to secure a balance.

* Hartshorn, *Proc. Phys. Society*, Vol. 36, 399, 1924.

† Schering, *Zeitschr. fur Instr.*, Vol. 40, 124, 1920.

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Then, if c_5 is diminished by a small amount, *e.g.*, by disconnecting one of the leads to it, K will have to be increased by the same amount to maintain a balance. If, however, K consists of two condensers c_1 and C_1 in series (Fig. 2*b*), of which $C_1 = nc_1$, and the change in c_5 is taken up entirely upon the larger unit C_1, then it can be shown that the amount by which K has changed will be

$$\left(\frac{c_1}{c_1+C_1}\right)^2 \text{ or } \left(\frac{1}{n+1}\right)^2$$

of the amount by which C_1 has to be altered to compensate for it. This is only strictly true for small changes in C_1. A more accurate expression for deducing the change k in K in terms of the original C_1 and the final value C_1' is given below:—

$$k = \frac{c_1^2}{(c_1+C_1)(c_1+C_1')}(C_1 - C_1')$$

By suitable choice of the value of "n" a wide range of magnification may be provided. For the purpose of these tests the authors used the following values of c_1 and C_1. c_1 consisted of a fixed mica condenser of ·001 microfarad. C_1 in addition to a mica condenser of ·01 microfarad had a standard variable air condenser of a maximum capacity of ·002 microfarad in parallel with it. Thus $c_1 = ·001$; $c_1 + C_1 = ·013$ (approx.), gave a magnification of the order of 160, permitting measurements correct to 1/100 micro-microfarad to be secured by reading off the standard condenser to the nearest micro-microfarad.

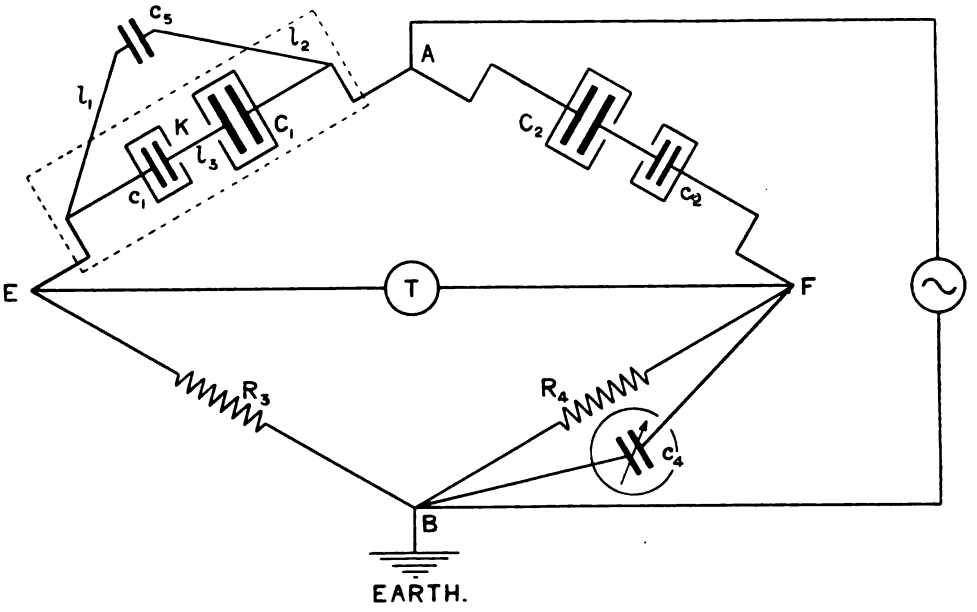

Fig. 3.

Such are the simple elements upon which the method rests. The manner in which they are utilised is indicated in Fig. 3.

(*c*) *Practical Details.*

The condenser to be tested is C_5. By means of a pair of rigid leads (l), it may be inserted in Arm No. 1 of the bridge in parallel with the combination standard K_1 made up of the two condensers c_1 and C_1. Arm No. 2 of the bridge is practically a duplicate of Arm No. 1, the idea being to make the bridge as symmetrical as possible. Arms 3 and 4 consist of non-inductive resistances each of 5 000 ohms, and in parallel with one of these is a small variable condenser (C_4) which is for the phase angle adjustment. As the value of C_4 could not be reduced to zero, it was necessary to balance its minimum capacity by means of a small fixed capacity connected across the ratio arm R_3. For

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this purpose a short length of flex was found very convenient, as a suitable value could be obtained merely by choosing an appropriate length. R_3, R_4 and C_4 are all enclosed in metal screens which are connected to the earthed point B of the bridge. The screens of the large condensers C_1 and C_2 are connected to the point A. Their capacities to earth are thus merely a shunt across the whole bridge, and do not affect the balance. The screens of c_1 and c_2, which are much smaller, are connected to the points E and F respectively. Their capacities to earth are shunted across the arms R_3 and R_4. They thus are balanced one against the other. These condensers must be placed as far away from the observer as possible, so that their capacities to earth are as little as possible affected by his movements. These earth capacities can, of course, be entirely eliminated (being located at the corners of the bridge) by Wagner's earthing device, but this is an additional complication. In the arrangement shown, since the impedances of the Arms 1 and 2 are enormous compared with those of 3 and 4, the points E and F are not much above earth potential, and thus the earth capacities at these points are only of comparatively small effect. The extreme fineness of adjustment referred to above would, of course, be of no advantage unless the bridge could be made correspondingly sensitive. It is comparatively easy to do this with the Schering Bridge. The voltage applied to the points A and B is simply raised until the sensitivity is sufficient. The current carried by the resistances R_3 and R_4 has to pass across the very high impedances in Arms 1 and 2 of the bridge, so that this current is always small. The voltage which can be applied is only limited by what the condensers will stand. Several hundreds of volts may be used quite safely in nearly all cases. In some cases, of course, it will not be desirable to use such high voltages for other reasons. The bridge takes very little power, and thus a very small transformer is sufficient to step up the voltage to the required amount. In practice the leads to the bridge were connected to a coil of several henries inductance, and this was brought near to the inductance coils of an oscillating valve set until the required voltage was obtained.

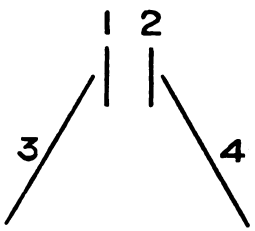

Fig. 4.

The capacities c_1 and C_1 include the capacity between the lead l_3 and the screen of the condensers. This must not be lost sight of in making the calculations. The lead should be of fine wire, and this lead capacity will be very small, and will not depend very much on the length of lead beyond 10 cm., say. The capacity between the two screens is merely added to the total capacity in Arm 1 and does not affect the ratio $(C+c)/c$.

(*d*) *Effect of the Leads.*

In Fig. 4 let 1 and 2 be the plates of the small condenser, whose capacity is to be determined and let 3 and 4 represent the leads used to connect the condenser to the bridge. This system of four conductors possesses ten capacity constants, viz., C_{1e}, C_{2e}, C_{3e}, C_{4e} the earth capacities, and C_{12}, C_{13}, C_{14}, C_{23}, C_{24}, C_{34} the mutual capacities. The quantity to be determined is C_{12}. It is to be noted that the bridge arrangement described above measures mutual capacities only. The earth capacities on the A side of Arm 1 may be regarded as a shunt across the whole bridge, having no effect on the balance, while those on the E side act as a shunt across R_3, and are balanced by adjusting C_4. Thus, in considering the capacity balance we may ignore all capacities to earth. The procedure to be adopted is as follows :—

(*a*) Connect 1 and 2 to 3 and 4 respectively, and note the bridge reading when balance is obtained. The effective capacity between the leads is now the inter-capacity of the two combined conductors 1, 3 and 2, 4—*i.e.*, of $C_{12}+C_{14}+C_{32}+C_{34}$.

(*b*) Break the connection 1—3 without disturbing the lead appreciably, connect 1 to earth, and again take the balance reading. The capacities C_{12}, C_{14} have now become earth capacities, and are thus eliminated, and the effective capacity between the leads is $C_{32}+C_{34}$.

(*c*) Again make the connection 1—3, break the connection 2—4 and earth 2. The balance reading now corresponds to a capacity between the leads of $C_{14}+C_{34}$.

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(*d*) Break both the connections 1—3 and 2—4 and earth both 1 and 2. All the capacities except C_{34} now become earth capacities, and thus the effective capacity between the leads is now C_{34}.

Taking the differences of the readings (*a*)—(*d*), (*b*)—(*d*), (*c*)—(*d*) we obtain the values of $C_{12}+C_{14}+C_{23}$, C_{23}, and C_{14} respectively, and thus C_{12} may be determined. The positions of the conductors must not be disturbed in taking any of the readings or some of the capacities may be changed. For example, the capacity between the leads C_{23} is influenced by the presence of the plates 1 and 2, and thus the leads reading must be taken with 1 and 2 in position.

As a check of the method employed a case was investigated in which the capacity was amenable to calculation and the remarkable degree of agreement is evidenced by the results quoted in the proceedings of the Physical Society of London (*loc cit*).

(*e*) *Application to a Valve.*

The three electrodes of a valve form a system of conductors possessing three mutual capacities: C_{ga}, C_{fg}, C_{fa}. Each of these was measured separately in the precise manner described above. The electrode not actually under observation must be earthed during a series of measurements, *e.g.*, while taking the four observations necessary to determine C_{fa} the grid must be earthed. If this is done, our method measures the true mutual capacity C_{fa}, which is a measure of the number of lines of force for a given voltage passing from filament to anode through the spacings of the grid. If the grid is not earthed, and the method of measurement does not allow the elimination of earth capacities, then what is measured approximates to the total capacity between filament and anode C_{fa}', where

$$C_{fa}' = \frac{C_{fg}C_{ga}}{C_{fg}+C_{ga}} + C_{fa}$$

This is a measure of the total lines of force passing from filament to anode, including those which pass from filament to grid, and then from grid to anode. (These are represented by the first term in the above equation.) In practise C_{fa} is the important constant, and this is determined directly by the above method.

Specimen Test.

In the first instance we shall give a specimen set of results showing the magnitude of the extraneous inter-capacities to be eliminated in their relation to those that are to be measured. Coupled with the fixed (values $c_1 = 1\,025$ micro-microfarads and $c_1 + C_1 = 11\,132$ micro-microfarads) we have the readings of the variable air condenser. These readings are given below in the table, where the cases (*a*), (*b*), (*c*) and (*d*) have the significance attached to them above.

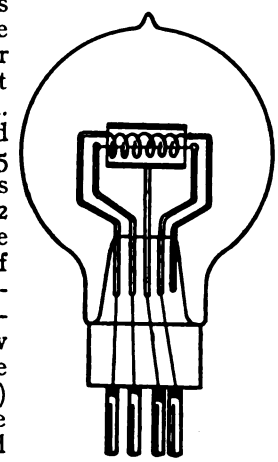

Fig. 5. "*R*" *Type Valve.*

Valve A. Holder X. (*See Fig. 7, p. 269.*)

Case	Variable Condenser Readings $\mu\mu$F.	Differences.	Capacity differences.	Inter-electrode capacity. $\mu\mu$F.
	Filament to Grid. (*Anode earthed.*)			
(*a*)	1 017	908	6·02	5·79
(*b*)	1 899	26	0·16	
(*c*)	1 913	12	0·07	
(*d*)	1 925			
	Filament to Anode. (*Grid earthed.*)			
(*a*)	1 184	740	4·83	4·60
(*b*)	1 189	27	0·17	
(*c*)	1 914	10	0·06	
(*d*)	1 924			
	Anode to Grid. (*Filament earthed.*)			
(*a*)	1 483	445	2·77	2·66
(*b*)	1 920	8	0·05	
(*c*)	1 918	10	0·06	
(*d*)	1 928			

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Results.

(a) *R Valves and their Holders.*

We now give the values for three R valves of the same make taken at random. The variations in capacity from one valve to another are quite considerable when allowance is made for the holder.

Valve.	Holder.	Capacity in $\mu\mu$F.		
		C_{fg}	C_{fa}	C_{ga}
A	X	5·79	4·60	2·66
B	X	6·11	4·92	3·16
C	Y	7·70	5·99	3·67

These results may be taken as typical of an R type valve. It is instructive to compare them with the V type valve.

Type.	Capacity in $\mu\mu$F.		
	C_{fg}	C_{fa}	C_{ga}
R	5·79	4·60	2·66
V	0·95	0·98	1·64

The actual size and disposition of the active part of the electrodes is roughly the same in the two cases, but the capacities in the R type are several times greater than for the V type. This, of course, means that the greater part of the capacity in the R type valve lies in the leads in the pinch of

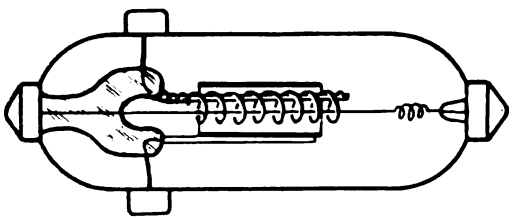

Fig. 6. *V-24 Valve.*

the valve. Again, in the V type valve, the capacities to the filament are the smallest, which is to be expected since the filament is the smallest electrode ; but in the R type, they are by far the largest, which is due to the fact that the filament has two leads in the pinch of the R valve and each of these had considerable capacity to the other leads.

In the previous table it will be observed that the third case differs from the other two as regards valve-holder. This led to our investigating the contribution of the two valve-holders separately. Valve-holder "Y" was of the usual commercial embedded type, whereas "X" had its sockets supported on good ebonite and surrounded by air. The lower values of A and B are due to this difference as will be made clear by a comparison of the figures for the holders themselves.

Holder.	Capacity of sockets, $\mu\mu$F.		
	C_{fg}	C_{fa}	C_{ga}
X	1·11	0·86	0·19
Y	2·65	2·08	1·16

It will thus be obvious that the holder contributes very largely to the effective inter-electrode capacities of this type of valve, and that the holder with sockets embedded in insulating compound is at a disadvantage as regards capacity. In fact, the results endorse the comment made in the comparison of the R with the V type of valve.

Before we leave the R type we include figures for two valves of a different make from the others.

R Valve.	Holder.	Capacity in $\mu\mu$F.		
		C_{fg}	C_{fa}	C_{ga}
Horizontal Filament	X	5·71	5·72	2·38
Vertical Filament	X	11·25	9·09	4·27

Here it is obvious that the second valve is much inferior to the first from the point of view of capacity. The bridge readings also showed that in the second case the capacities were of much higher power factor. On close examination of the two valves it became evident that the difference was due to the black insulating compound in which the pins of the valve are set. It was of a different nature in the second case and probably of poorer quality.

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Values of three types of D.E. valves are given below :—

Valve.	Holder.	Capacity in $\mu\mu$F.		
		C_{fg}	C_{fa}	C_{ga}
A	X	5·94	4·78	2·43
B	X	5·86	5·32	3·01
C	X	5·27	4·24	2·04

(*b*) *Power Valves.*

Two specimens of Power Valves were tested and gave the following results :—

Valve.	Holder.	Capacity in $\mu\mu$F.		
		C_{fg}	C_{fa}	C_{ga}
Power Amplifying	X	8·13	5·88	4·42
Trans-mitting (T)	—	6·37	2·30	4·55

Here the larger valve (T) has the smaller capacities. This, of course, is due to the fact that the T valve is used without a holder.

(*c*) *V Valves and Holder.*

We shall now give a few figures referring to the V type and for the clip-holder in general use with this class of valve.

Valve.	Holder.	Capacity in $\mu\mu$F.		
		C_{fg}	C_{fa}	C_{ga}
A	Z	1·25	1·16	1·71
B	Z	0·71	0·84	1·72
C	Z	0·98	1·16	2·01
D	Z	0·95	0·98	1·64

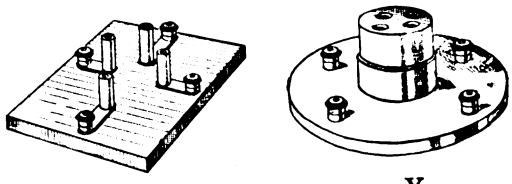
The following values for the clipholder Z are probably only correct to within about ·03$\mu\mu$F, owing to difficulties of contact with bridge leads.

	C_{fg}	C_{fa}	C_{ga}
Clip-holder Z	0·10	0·16	0·12

These values compare very favourably with the four-pin holder. It will be observed that we have not attempted to derive from the combined capacity of holder and valve the amount residing in the valve itself. The direct difference will only give it approximately.

(*d*) *Coil Holders.*

Finally, we give values obtained for various coil holders. Cases A, B and C were of the one pin, one socket type mounted up



X Y

Fig. 7.

on a spindle complete with leads of single flex 8 cm. long about 1·5 cm. apart to the terminals (Fig. 10). Case D was tested with its lead on and its lead off. The lead in this case consisted of about 12 cms. of twin flex. Case E was just one pin and one socket in an ebonite block.

Coil Holder.	Capacity between terminals, ($\mu\mu$F).
A	5·51
B	5·52
C	6·13
D	>12·0
D (without lead)	0·98
E	1·64 —

What is very striking about these figures is that an elaborate design of a coil to overcome self-capacity is of little value when a coil holder of the type D (with lead) is used.

Some Effects of these Capacities in Practice.

Confining our attention to the grid-filament circuit, we can indicate approximately the upper limits of frequency to which each of the preceding types can give rise. Let us assume that the coils employed are circular, of radius a and made of wire of radius r. An approximate value of their inductance at high frequencies can be obtained from the formula

$$L = \frac{4\pi a n^2}{1\,000}\left(\log_e \frac{8a}{r} - 2\right) \text{ microhenries}$$

where the number of turns n only slightly exceeds unity.

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Taking 12 inches as a convenient diameter for a coil, we obtain for wires of the gauges mentioned the inductance quoted below :—

No. 6 S.W.G. 1 turn : Inductance = 0·81 microhenry.
2 turns : Inductance = 3·24 microhenries.

No. 18 S.W.G. 1 turn : Inductance = 0·99 microhenry.
2 turns : Inductance = 3·95 microhenries.

Suppose that we take mean values for the two cases, viz. (*a*) 1 turn : ·9 microhenry ; (*b*) 2 turns : 3·6 microhenries. To get a frequency of ten million cycles per second the capacities required for tuning will be (*a*) 280$\mu\mu$F, (*b*) 70$\mu\mu$F.

Coming to the types of valves measured it will be obvious that the extreme frequency attainable will be given by

$$(a)\ \sqrt{\frac{28\,000}{C_{fg}}}$$

$$(b)\ \sqrt{\frac{7\,000}{C_{fg}}}\ \text{million cycles per second.}$$

R. Type. C_{fg} (mean) $\doteqdot 6\mu\mu$F.

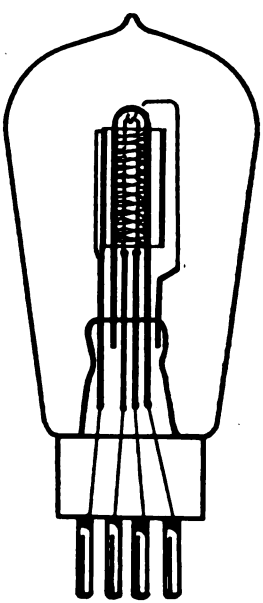

Fig. 8. *L.F. Power Amplifying Valve.*

(*a*) $n_{(max.)}$ = 68 million cycles per second ;
$\lambda_{(min.)}$=4·4 metres.

(*b*) $n_{(max)}$. = 34 million cycles per second ;
$\lambda_{(min.)}$=8·8 metres.

V type. $C_{fg(mean)}$ $\doteqdot 1\mu\mu$F.

(*a*) $n_{(max)}$ = 167 million cycles per second ;
$\lambda_{(min.)}$=1·8 metres.

(*b*) $n_{(max.)}$ = 83 million cycles per second ;
$\lambda_{(min.)}$=3·6 metres.

These figures, it will be understood, leave no margin whatever for a variable condenser for tuning purposes, and are based solely upon the measured geometrical capacity of the elements concerned. In practice the effective values would most certainly differ from those measured, but would still be functions of them. To derive an idea of the effective capacity in the input circuit under working conditions great assistance is rendered us by a theoretical treatment initiated by Mr. J. M. Miller,* and substantiated by him as a result of a thorough experimental investigation. He deduced that the existence of the capacities between the elements of a three-electrode vacuum tube causes the input impedance of the tube to depend upon the nature of the load in the plate circuit. Representing the input impedance by an apparent resistance r_g in series with an apparent capacity C_g, he obtained values for C_g under various conditions prevailing in the plate circuit. If the resistances in the output circuit of the valve be r_p (internal), and R_p (external), and μ be the amplification factor, then, for the case of a pure resistance load in the plate circuit, C_g may have the following values :—

Case (1). At low frequencies where terms in ω_2 are negligible,

(say, $\omega < 10^6$)

$$C_g = C_{fg} + C_{ga}\left(1 + \frac{\mu . R_p}{r_p + R_p}\right)$$

This gives for a maximum increase over C_{fg} the amount $(\mu+1)\ C_{ga}$, when R_p is large compared with r_p.

Case (2). For very high frequencies where terms in ω^2 predominate,

$$C_g = C_{fg} + \frac{C_{ga} . C_{fa}}{C_{ga} + C_{fa}}$$

This case applies more particularly to the circumstances under discussion. Here C_g is virtually the capacity between filament and grid when the plate circuit is open, *i.e.*, C_{ga} and C_{fa} in series across C_{fg}.

Proceeding now to observe the effect of these considerations upon our deductions of $n_{(max.)}$ for the types of valves discussed above, we find at high frequencies that C_g for the *R* valve exceeds C_{fg} to the extent of 30 per cent. so the $n_{(max.)}$ will be 15 per cent. lower than we derived in assuming it to be C_{fg}. In the case of the *V* valve we find C_g to be 60 per cent. greater than C_{fg}, which results in a diminution of 30 per cent. in the estimated $n_{(max.)}$

* Miller, *Bulletin Bureau of Standards*, Vol. 15, 367, 1919.

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At low frequencies we find a very marked difference between C_g and C_{fg}. The actual difference depends upon the relative magnitude of r_p and R_p, and can amount in an extreme case to as much as :—

R valve. $\mu=9$; $C_g=32\mu\mu F$, as compared with $C_{fg}=6\mu\mu F$.

V valve. $\mu=6$; $C_g=12\mu\mu F$, as compared with $C_{fg}=1\mu\mu F$.

From the practical point of view the importance of this high value rests in the fact that it corresponds to a large consumption of power in the input circuit.

We wish to state that the measurements here described were made with current of telephonic frequency. Radio frequencies could be used and could probably be made to yield much higher sensitivity with a suitable detector (*e.g.*, a heterodyne arrangement with an amplifier, if necessary). However, the variations of capacity with frequency are known to be exceedingly small from the point of view of such measurements, and the choice of working frequency is solely a question of available apparatus and convenience.

Power Factor Measurements.

It is obviously important to obtain an idea of the power factor of the various capacities we have investigated. A high power factor means loss of energy and therefore a decrease in efficiency. We have mentioned that in our bridge the phase angle or power factor adjustment is provided for by the small variable air condenser C_4. This small condenser also plays a part in the elimination of earth capacities, and in order to avoid confusion, we have found it desirable, when accurate capacity measurements are required, first to determine the capacity as described above without paying any particular attention to power factor readings. Then, if power factors are required, they are determined by another set of measurements. If, however, the capacity is required only approximately, then it is possible by means of two observations only, to determine both capacity and power factor. In this case the procedure is as follows :—

(*a*) Connect up the valve to the bridge exactly as before, earthing the third electrode. When balance is obtained, note the capacity reading and also the C_4 reading.

(*b*) Disconnect the valve from the lead attached to the point A of the bridge,

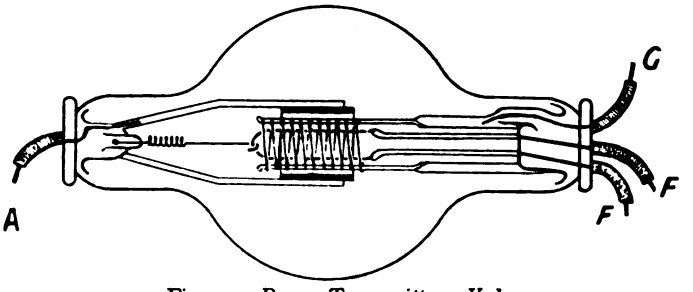

Fig. 9. *Power Transmitting Valve.*

disturbing the lead as little as possible. Again, balance and note the new reading of C_4 and also the capacity reading.

The difference between the two capacity readings gives the capacity of the valve approximately. The effect of leads is not entirely eliminated. Our previous measurements show that the probable error is about $0{\cdot}1\mu\mu F$. If ΔC_4 is the difference between the two C_4 readings, then it is easy to show that the power factor of the valve capacity measured is approximately

Power factor =

$$\frac{C}{c}.\Delta C_4.r_4.\omega\times 10^{-6}$$

where C = total capacity in Arm 1 of bridge.
c = capacity of valve (difference in C readings).
$\omega = 2\pi\times$ frequency.
ΔC_4 = difference in C_4 readings (in $\mu\mu F$).
In our case $C=945\ \mu\mu F$.
$r_4 = 1\,000$ ohms.
$\omega = 5\,000$.

so that

$$\text{Percentage Power Factor} = 0{\cdot}472\ \frac{\Delta C_4}{c}.$$

Here both ΔC_4 and c are in $\mu\mu F$.

In taking the second reading for power factor it is important not to disconnect the valve from the lead attached to the point E of the bridge. This would affect the value of C_4 and thus introduce error into the power factor measurement.

Power Factors of Valves.

Using this method, two R valves were tested to obtain a rough estimate of the power factor of the three capacities C_{fg}, C_{fa}, C_{ga}. As it happened, the two were of a

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different make, although there is nothing outstandingly different about them.

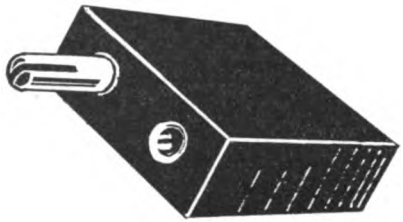

Fig. 1. *Coil-holder E.*

R Valve I.

$C_{fg}=5{\cdot}98\mu\mu F.$	$C_4=99\mu\mu F.$	P.F.= 7·8%
$C_{fa}=4{\cdot}90\mu\mu F.$	$C_4=100\mu\mu F.$	P.F.= 9·6%
$C_{ga}=2{\cdot}84\mu\mu F.$	$C_4=17\mu\mu F.$	P.F.= 3 %

R Valve II.

$C_{fg}=6{\cdot}05\mu\mu F.$	$C_4=115\mu\mu F.$	P.F.= 9·0%
$C_{fa}=4{\cdot}95\mu\mu F.$	$C_4=120\mu\mu F.$	P.F.=11·4%
$C_{ga}=3{\cdot}19\mu\mu F.$	$C_4=88\mu\mu F.$	P.F.=13·0%

V Valve.

In this case the power factor was found to be less than 1 per cent. $C_{ga}=1{\cdot}79\mu\mu F.$ $C_4=2\mu\mu F.$ P.F.=0·5 per cent.

The valve of high power factor previously referred to had succumbed before these tests were inaugurated, else we might have fixed a probable upper limit to the power factors to be met with in practice. It is not very apparent why there should be such a difference in the power factor values for the capacities C_{ga} in the two R valves. The only obvious difference was in the greater separation of the leads in the pinch of the valve I. Absence of homogeneity in either the glass or the black insulating compound could give a possible explanation. A difference from 500 to 2 400 megohms in the insulation resistance would suffice. Nothing is more certain than that the divergency exists.

Distribution of Capacity in a Valve.

The same method of attack enables one to estimate the distribution of capacity and power factor amongst the various sections of a valve. Tracing the leads from any two pairs of electrodes, *e.g.*, anode and grid, we discern four distinct localities. Referring to the diagram (Fig. 11) there are the capacities :—

(*i.*) Due to the electrodes proper at A.

(*ii.*) At B in the pinch where the leads are embedded in glass as dielectric.

(*iii.*) At C where the dielectric is gaseous ; and

(*iv.*) At D where the pins are surrounded by a black insulating compound.

These regions of different dielectrics will make unequal contributions to the capacity and to the power factor of the complete valve. Before proposing to cut down either the capacity or the power factor of a valve it is very necessary that manufacturers should obtain an estimate of the quantities involved so as to know the vital points where each enters to the largest extent. By way of obtaining such an estimate a disused valve, in which only the grid and anode elements remained intact, had its envelope removed and was set up in a holder. The capacities between the terminals were measured simultaneously with observations of their power factor under the conditions given below :—

(*a*) First of all the valve was taken as it stood.

(*b*) Secondly, the electrode projections above the glass pinch were removed.

(*c*) Thirdly, the glass pinch was crushed leaving only the leads in air.

(*d*) Fourthly, the leads that still penetrated above the black substance were clipped off.

(*e*) Fifthly, the pins were removed out of the sockets leaving only the holder.

(*a*) Gave the total capacity.

(*a*) – (*b*) The capacity due to the electrodes themselves, A.

(*b*) – (*c*) The capacity located in the glass pinch, B.

(*c*) – (*d*) The capacity due to the leads in air C.

(*d*) – (*e*) The capacity contribution in the black compound, D.

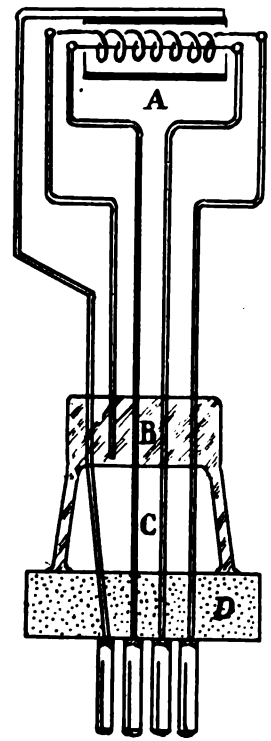

Fig. 11.

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Readings.	Capacity $\mu\mu$F.	Power Factor.
(a)	3·82	0·21
(b)	1·65	0·31
(c)	1·11	0·24
(d)	0·97	0·23
(e)	0·26	0·00

Hence the contribution due to the sections are given roughly :—

	Section.	Capacity $\mu\mu$F.
Electrodes ..	A	2·17
Pinch	B	0·54
Leads to pinch	C	0·14
Pins	D	0·71

It would not be safe to make a quantitative deduction of power factor, but an examination of the results indicates that the power factor is higher in the glass than in the black insulating compound.

In any case the power factor values appear extremely high and are, undoubtedly, higher in contact with air than they would be in vacuo under working conditions in the absence of moisture, etc. A comparison with the previous set of results obtained with sealed valves would indicate this. Nevertheless, when such small capacities are involved an insulation resistance as low as 1 000 or even 10 000 megohms has an astounding effect on power factor and this could easily be accounted for by surface leakage.

A Year Ago.

By Léon Deloy (F8AB). **[R545·909**

Our contributor—the well-known French amateur who was one of the pioneers of short-wave transatlantic communication—reviews the work that has been done in the same direction since his success.

IT is just over a year since there was established the first short-wave transatlantic communication, which took place between amateur stations—that of my friend Mr. F. H. Schnell, at Hartford, Connecticut, and my own station at Nice. This achievement created considerable excitement at the time, and the news rapidly spread through the world, the most startling point at that time being that the communication took place on about 100 metres, a wave-length which up to that time had been considered incapable of reaching long distances. The immense possibilities of long-range work with these short waves were immediately appreciated, and both Government and commercial stations busied themselves in studying on the new lines. The time now seems opportune to indulge in a short review of the results of this development. First, however, it is necessary to see what was the position a year ago, and how those early experiments of ours were carried out.

After the war, wireless amateurs were much more numerous in all countries than had been the case before. Most of them had been engaged in wireless work during the war, and were anxious to continue experimental work after demobilisation. After considerable hesitation, most of the Governments involved ended by assigning to amateurs a band of wave-lengths for transmission somewhere between zero and 200 metres. It seems fairly obvious that this band was thrown to amateurs like a bone is to a dog, because it was considered practically useless for serious work at more than a few miles. While we saw on every side giant commercial stations with dozens of masts hundreds of feet high, and aerials a mile or two long, the unfortunate amateur—limited to 200 metres for wave-length and a kilowatt of input power in France (in most

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cases 10 watts in Great Britain)—was forced to devote his attention to getting the maximum efficiency from his station. The success of many amateurs was remarkable, and by means of endless patience and hard work, they succeeded in covering hundreds and then thousands of miles. As a general rule, professional engineers of the commercial companies were very sceptical. "What!" they said. "The amateur talks about crossing the Atlantic on 200 metres? He must be entirely ignorant of the laws of long range transmission." However, it was done. Amateur signals made themselves heard across the Atlantic. But in spite of steady efforts extending over three years, and experiments between the amateurs of U.S.A. and Canada on one side, and all Europe on the other, two-way work was never successful on the wave-lengths of 200 metres or thereabouts first used. It was only when some of us tried 100 metres that success came.

These short waves then had proved that they could cover considerable distances, but it still seemed hardly probable that they could be used for commercial purposes. Firstly, their range by day was very low; and secondly, even at night they were subject to curious fading effects which often made it extremely difficult to take down a complete message. I had always had confidence in the shorter waves by some sort of instinct, and when my station succeeded in being the first French one to be heard in America—one other European station beat me by two days—I was using 195 metres, although my licence allowed anything up to 300.

In May, 1923, I happened to be listening to a signal sent from Paris on 45 metres. I received this at Nice on a single valve with such strength night and day that it made a great impression upon me. Next month, in June, I heard even more strongly experimental transmission by Poldhu on 94 metres. I was so much impressed that although I was due to leave Nice for the summer within three days, I hastily rigged up a transmitter for 100 metres, and made some experiments. Signals were received very strongly at all hours, and from that moment I decided to attempt transatlantic work on 100 metres as soon as I returned to Nice in October.

During the summer I made a short tour of America, where I found wireless workers nearly as sceptical as here on the possibilities of short waves for any useful work. In fact, one specialist in short-wave work told me that he was absolutely convinced that they could never cover more than 500 miles or so. There were, however, some amateurs who were rather more optimistic, and eventually it was decided that we should make some experiments. On my return to Nice on October 28th I began immediately to reconstruct my station to work on 100 metres. Preliminary tests were carried out with England, whence I received reports of extremely strong signals. I then decided to try forthwith to get across to America, although my station was not really ready, and I could only just use 500 watts. I cabled to Schnell to tell him that I would be calling for an hour on the night of November 25th and 26th. On the first attempt he got me perfectly; the next day I passed him two messages, and by the 28th he had completed a 100-metre transmitter so that he could reply to me, and we were in touch all night, working with the greatest ease. An English amateur who heard this first transatlantic conversation wrote to me later:—

"It was really striking to see how easily the two of you were working, while at the same moment high-power stations were making desperate efforts to keep up regular communication, without result."

Schnell and I will never forget this morning of the 28th November, 1923, during which we succeeded at last in what had been for us the task of years. Hiram Percy Maxim, President of the American Radio Relay League, said during a speech which he made some months ago at Paris: "It may be difficult for others to grasp the emotion which we felt when we first heard in America the signals of 8AB."

All those who were present at this first experiment understood immediately the enormous effect which it was going to have on long-distance communication. From that moment I expressed the conviction that in less than five years the commercial traffic between Europe and America would be carried out entirely on short waves. Most people thought that I was exaggerating the practical possibilities of this system. I had on the other hand under estimated, and only about five months later commercial telegrams were being exchanged between the old and new worlds in this manner. But let us return again to November 28th, 1923, and continue our notes on the progressive development of short-wave work.

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That same morning, after having been working for an hour with Schnell, I received a signal from Reinartz, who had hastily brought down his wave-length to 100 metres, and had got over to me at the first attempt. During the following days, numerous stations came down to 100 metres, both American and Canadian, then English and other French stations, till finally Dutch and Italians. This wave-length of 100 metres seemed to be almost magic; stations which had for years been making fruitless efforts to cross the Atlantic, succeeded immediately on the short wave. One could maintain communication with powers of 20 to 30 watts, and the most remarkable fact was that in this work one did not get the periodic fading which had hindered work on 200 metres.

Immediately, official and commercial wireless engineers interested themselves in the question: the saving which might result from short-wave low-power working could not be neglected. For example, a high-power station with a range of 10 000 miles or so would probably be of many hundred kilowatts, with an enormous aerial. The capital expenditure on it would very likely be half a million pounds, a large staff is required to run it, and the cost of supplying energy is heavy. On the other hand, a short-wave station of equal range could very likely be set up at the cost of £20 000 or £30 000, its staff would consist of one or two, and the consumption of power would be at the rate only of three or four kilowatts. In France, the Ministry of War, and then that of Posts and Telegraphs, were much interested in my work, and shortly afterwards the Eiffel Tower undertook a series of transmissions on short waves with the idea of accumulating scientific data on the propagation of these waves. In England, the Marconi Company took up again the transmissions from Poldhu, and in a few months succeeded in making telephony heard right to the Antipodes, with the result that the Australian Government decided immediately on the construction of a short-wave station to communicate directly with England. In America, all the great commercial companies, and also the Navy, devoted much energy to the study of short waves, and in Italy Signor Ducati, the first Italian amateur to succeed in transatlantic working at 100 metres, was asked by the Navy to install a two kilowatt station of this kind at Rome and another on a warship which was crossing to South America. It was enabled to keep in direct communication with Rome on 100 metres during the whole of the journey. In France and Germany the great commercial companies experimented on direct traffic with South America with 100 metre waves, and in most cases it was found that Buenos Ayres received easily short-wave messages from France with only a few kilowatts behind them, while, at the same time, it could not receive long-wave signals sent with a power of several hundred kilowatts.

During all this time, amateurs the whole world over, were using these waves, and communication was established between different continents with extraordinary ease. Recently, as we all know, there has been regular communication between Europe and New Zealand, and a certain amount of work with Australia, using a power of a few hundred watts and apparatus capable of being housed completely in a small cupboard. This is evidently only a beginning. Modern short-wave work is only a year old, and the enormous progress which has been made in this short time gives us great hope for the future. The most important thing is to increase the range by day, but the solution to this problem is well on the way. Already we have succeeded on many occasions, and it seems that by the use of shorter waves still, between 80 and 30 metres, one may have permanent success, and, in fact, find work easier by day than by night. The consequences of this revolution in communication will certainly be of great importance. Certainly it will shortly permit a reduction in the tariff for commercial telegrams to a small fraction of what it has been hitherto. Practical telephony between the most distant parts of the earth should now only be a question of months. Direct touch between a ship or airship and its port will be possible wherever the ship may be, and, lastly, there is the enormous avenue of private communication with friends across the world. Let us hope that this last application of short-wave work will have the important influence that one would expect in bringing peoples into touch with one another, and making future wars impossible.

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Our Calibration Department.

[R206

Readers are asked to note carefully the new organisation of this department.

AT the moment of writing, our two main standards have not yet returned from the N.P.L., but we have every hope that they will be back with us before this is in the hands of our readers, and we have pleasure in stating that we are now again ready to receive apparatus; but under rather different conditions.

To prevent misconception, we should like to state that the new conditions do not apply to existing subscribers until the end of their present subscription.

The new conditions, briefly, are that in future we shall make a charge for calibration work, but at the same time the service will be thrown open to all readers.

Details of the Service.

We give now the types of instruments, etc., which we can test, the fees for each type of calibration, and the approximate accuracy with which we can do the work. It must be clearly understood that a general statement as to accuracy does not necessarily mean that this accuracy will be maintained by the apparatus after test. Just as an example, we have had wave-meters sent in which could certainly not be depended on to repeat their readings within 5 per cent., owing to bad condensers, coils on non-rigid formers, etc.

Further, we make no attempt to compete, as to accuracy, with the great testing institutions, such as the N.P.L., Faraday House, etc., to whom should be sent all laboratory standard and sub-standard instruments. Perhaps we may be permitted to state that the fees charged do not cover more than about one-third of the bare labour cost of testing.

General Conditions.

Readers desiring tests not mentioned in the list below should write and inquire what can be done, as we can often make special arrangements for other types of work.

When sending apparatus, please send a letter *under separate cover*, enclosing the calibration coupon cut from the advertisement pages of the number of E.W. & W.E. current at the time, also the cost of return postage or carriage, the appropriate fee, and the technical information asked for in connection with the particular work to be done.

All apparatus must be sent carriage paid.

Apparatus must be securely packed; all instruments and heavy components should be in wooden cases with ample packing material; it is particularly requested that screws and *not* nails be used for the lids.

Each separate item or part must have securely fixed to it a label with the name and address of the sender.

Although every care is taken of all apparatus, we accept no responsibility whatever for loss or accidents either in transit or in our hands.

Please see that apparatus is in proper order before despatch; valve wavemeters which do not oscillate, buzzer wavemeters which do not buzz, and instruments of indifferent quality (and therefore unlikely to maintain reasonable accuracy) are liable to be returned uncalibrated.

Details of Tests.

WAVEMETERS, for wave-length at various settings.

Valve Wavemeters.—These can be calibrated for any frequencies between 5 000 and 15kC (60 to 20 000 metres) to approximately 1 per cent. accuracy.

Fees.—For a single range, 2s. For each additional "range," *i.e.*, swing of condenser over its full scale, add 1s.

E.g., a meter with two sets of coils and to be used with or without a parallel fixed condenser has four ranges, and the fee would be 5s.

Valve wavemeters must be accompanied by the actual valve to be used.

Information required.—Filament, anode, and grid volts to be used; minimum and maximum wave-lengths expected on each range.

Buzzer Wavemeters.—These can be calibrated between 3 000 and 50kC (100 to 6 000 metres) to 2 to 4 per cent. according to quality.

Fees.—For first range, 1s., each additional range 6d. (For "range," see above under valve wavemeters.)

Information required.—Voltage required for buzzer if battery not enclosed in meter; minimum and maximum wave-lengths expected on each range.

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CONDENSERS.

Fixed condensers, of not more than ·002μF, can be measured at one radio frequency, to approximately 1μμF. Condensers can be tested for H.F. resistance; see under that heading.

Fee.—9d. For sets of condensers sent at same time, 6d. for each after the first.

Information required.—Which terminal it is desired to have maintained at earth potential during test.

Larger condensers are tested at audio-frequency to approximately 1 per cent.

Fee.—1s.; for sets of condensers sent at same time, 9d. for each after the first.

Variable condensers.—These can be calibrated at any one radio frequency, between 500 and 30kC (600 to 10 000 metres) to approximately 1μμF.

Fee.—1s. plus 3d. for each position tested. Unless special arrangements are made we test at 12 positions over the scale, making a total fee of 4s.

Information required.—Which terminal it is desired to have maintained at earth potential during test. Number of points to be tested. At what frequency it is desired to have the test.

Inductors, fixed, air core (we do not test iron-core coils).—Coils between about 50 and 50 000μH can be tested for inductance and self-capacity at radio frequency. The test extends over wave-lengths covered by the coil with capacities of about .0001 to .0005, and the inductance is assumed constant. Accuracy of inductance measurement approximately 1 per cent.; of self-capacity, about 10 per cent. Inductors can be tested for H.F. resistance; see under that heading.

Fee.—2s. 6d.; for sets of coils sent at same time, 2s. for each after the first.

Inductors, variable (variometers and tapped coils).—Each tapping or position of variometer will be treated as a separate coil.

Fees.—See above.

Information required.—For variometers, number of readings. For both types, which terminal is to be maintained at earth position during test.

Resistance, D.C.—Robust apparatus, capable of carrying normal bridge currents, can be tested for resistance to the following approximate accuracy: below 1 ohm 1 per cent.; 1 to 10 000 ohms 0·1 per cent.; above 10 000 ohms 1 per cent.

Fee.—9d.; for additional tests within the same group, 3d. each.

Delicate instruments, such as galvanometers, etc., are tested for resistance to 1 per cent. only.

Fee.—As for tests above.

Information required.—Maximum safe current

Resistance, H.F.—*Resistors* of 1 to 30 ohms, approximately non-reactive, can be tested to within approximately ·05 ohm at any one desired radio frequency between 2 000 and 15kC (150 to 20 000 metres).

Fee.—2s. 6d. Additional resistors sent at same time, or readings at other frequencies, 2s. each.

Information required.—Maximum safe current for delicate resistors; desired frequency of test.

Inductance Coils can be tested for total loss, expressed as equivalent series resistance, at any one radio frequency within the range of the coil with a capacity between ·000 2 and ·001μF. Accuracy, to ·05 ohm approx.

Fee.—As for resistors; but if the same coil is also to be tested for inductance, the extra 6d. for the first reading is not charged.

Information required.—As for other tests on Inductors.

Condensers can be tested for total loss, expressed as equivalent series resistance and/or power factor, at any one radio frequency between the above limits. Accuracy, to ·05 ohm approx. (A good air condenser should have a resistance scarcely measurable by us.)

Fee.—As for resistors. But if the same condenser is being tested for capacity the extra 6d. for the first reading is not charged. In the case of variable condensers 2s. for each setting or each frequency.

Voltmeters, D.C., of maximum reading 2 to 250 volts. can be tested to approximately 1 per cent. of maximum reading. If the scale is blank, only light pencil graduations will be put on.

Fee.—6d. plus 3d. for each reading.

Information required.—Approximate maximum voltage.

Ammeters, D.C., of maximum reading 10 micro-amps to 5 amps, can be tested to approximately 1 per cent. Conditions as for voltmeters.

Voltmeters, H.F., Moullin type, complete with plate ammeter, can be tested at any one radio frequency between 2 000 and 20kC (150 to 15 000 metres), to approximately 2 per cent. Limits of voltage ·1 to 10 volts.

Fee.—1s. plus 3d. per reading.

Information required.—Exact steady voltage to be applied to anode and grid, reading on plate ammeter with no applied H.F. voltage, whether voltmeter is of grid-leak type or not.

Milliammeters, H.F., complete, or thermo-junctions, can be tested at any one radio frequency within above limits of wave-length and accuracy. Limits of current 1 to 500 milliamps. Tests at larger and smaller currents can be carried out on D.C.

Fees.—As for H.F voltmeters.

Information required.—Approximate maximum current. In case of separate thermo-junctions, D.C. resistance of indicating instrument to be used with them.

Conclusion.

As stated above, this scale of fees does not apply to existing subscribers, for whom we shall carry out this work gratis as we have undertaken. It should be understood that this exemption only applies until the present subscription expires.

Lastly, may we appeal to readers to pack carefully, and only to send us reliable and robustly-built apparatus worthy of calibration. Thus they will save us much labour and trouble, and themselves much disappointment.

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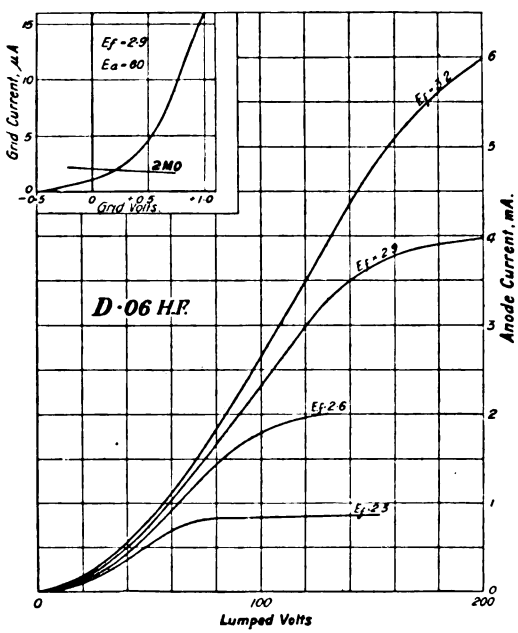
Six New Mullard Valves.

[R333·009

These are the four valves lately produced by the Mullard Co. for use on receivers for ordinary as distinct from power work, together with a new power valve Two of them supersede the D.F. Ora, while the other two are intended for operation off one cell of an accumulator. The power valve is one of extra-low current consumption.

The D·06 H.F.

THIS is rated as usual for the ·06 amp type of valve. We tested it at 2·3 to 3·2 volts. As regards its construction, the electrodes are of the usual cylindrical type, the ∩-shaped electrodes lately introduced by the Company for their new bright valves not being suited to dull emitters. Like the other valves of this group, the caps are entirely of moulded material, the usual metallic



outer cap having been discarded. They are sent out with a sealed wire shorting grid and filament, so that they cannot be used before sale, although the filament may be tested.

Our curves show the anode current under various conditions, and it will be seen that there is a fairly good "straight" working portion. The valve being sold as for H.F. work, one naturally does not insist on straightness to the extent required in an L.F. valve.

On examining the table, we see that the highest μ is got at low filament heat, as usual. Probably the best working heat is about 2·6 to 2·8 volts, as the impedance is here much lower. It will be noted that the filament takes a little more than its rated current. This, coupled with the value of 27 for the "filament efficiency" at 3·2 volts, inclines us to believe that the filament of the sample tested was a little on the thick side, and was running cooler than usual.

Fil. Volts. E_f	Fil. Cur. I_f	Sat. Plate Cur. I_s	Anode Imped-ance. R_a	Voltage Ampli. μ	Power Ampli. P $\left(=\frac{1\,000\mu^2}{R_a}\right)$	Filament Efficiency. F $\left(=\frac{I_s}{\text{Watts.}}\right)$
	mA.					
2·3	66	0·8	57 000	9·5	1·6	5·6
2·6	68	2·1	40 000	9·3	2·2	11·6
2·9	71	4·0	29 000	7·8	2·1	19·0
3·2	75	6·5	25 000	7·5	1·7	27·0

A grid-current curve at likely working values is also shown. The line marked 2MO cutting it shows the current through a leak of this valve connected to + of a four-volt battery. This value, or one rather lower, say 1·5MO, would seem likely to give results: it would probably be just as satisfactory to use lower filament heat and perhaps a lower anode voltage—say 2·7 and 60.

The D·06 L.F.

This appears to be a valve essentially similar to the one described above, but with the grid more open or of finer wire, giving lower μ and R_a. As will be seen from the curve sheet, the characteristics

Fil. Volts. E_f	Fil. Cur. I_f	Sat. Plate Cur. I_s	Anode Imped-ance. R_a	Voltage Ampli. μ	Power Ampli. P $\left(=\frac{1\,000\mu^2}{R_a}\right)$	Filament Efficiency. F $\left(=\frac{I_s}{\text{Watts.}}\right)$
	mA.					
2·3	65	1·3	44 000	7·3	1·2	8·6
2·6	69	2·6	25 000	5·8	1·3	14·5
2·9	73	4·7	20 000	5·3	1·4	23·0
3·2	76	7·5	15 000	4·5	1·4	32·0

are very good for straightness at voltages of 2·8 or over, and it is a further advantage that the low impedance and fairly low μ allow of the use of the necessary bias without needing very high anode voltages. Thus at 2·9 volts on the filament, where I_s is 4·7, full power will be got at an anode current of about 2·4mA, which requires 70 lumped volts. The permissible swing will be about 60

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anode volts (one from 40 to 100), equalling about 11 grid volts. This would mean 6 volts bias, and a battery of 100 volts would be sufficient. At 3·2 volts on the filament, this valve should handle a small loud-speaker quite well.

The grid curve shows that it will detect quite well, though the μ is rather low for this. It will be noted that grid current begins at about —0·3 volts, so for amplification this much must be added to half the input to get the least permissible bias.

The D·3 H.F.

As already stated, this is one of two substitutes for the L.F. Ora valve (which has now been on the market for a long time). It is rated at about ·3 amp, 1·8 volts, and we tested it at filament voltages of from 1·4 to 2·0V. The current varied from ·29 to ·36A, as will be seen from our table. The saturation current was larger than that of the corresponding ·06 type, rising to 11·0mA at full heat. The μ and R_a are nominally the same as for the ·06 type, but it will be seen that there are curious differences in the effect of filament heat on μ and the factor we have called "P." The "filament efficiency" of 15 at full heat is normal for this type of valve.

Fil. Volts. E_f	Fil. Cur. I_f	Sat. Plate Cur. I_s	Anode Imped-ance. R_a	Voltage Ampli. μ	Power Ampli. P $\left(=\frac{1\,000\mu^2}{R_a}\right)$	Filament Efficiency. F $\left(=\frac{I_s}{\text{Watts.}}\right)$
1·4	·29	1·0	80 000	8	1·8	2·5
1·6	·31	2·0	50 000	10	2·0	4·0
1·8	·34	5·7	33 000	9	2·5	9·2
2·0	·36	11·0	25 000	9	3·2	15·0

We show the grid current at 1·9V on filament and 100 on anode, also the straight line characteristic of a 2MO leak connected to filament positive. It would seem that a rather lower leak would bring the working point nearer the bend and give the best detection, although the exact figure would, of course, depend on the chosen filament and anode voltages.

The D·3 L.F.

This, the companion valve to the last, is intended for L.F. work, and is designed with a more open grid, to give low impedance. We tested it at the same filament voltages as used for the D·3 H.F., and found the filament to take a fraction more current, while it gave twice the output, the anode current rising to 20mA at full heat.

Fil. Volts. E_f	Fil. Cur. I_f	Sat. Plate Cur. I_s	Anode Imped-ance. R_a	Voltage Ampli. μ	Power Ampli. P $\left(=\frac{1\,000\mu^2}{R_a}\right)$	Filament Efficiency. F $\left(=\frac{I_s}{\text{Watts.}}\right)$
1·4	·31	2·5	37 000	4	1·3	5·7
1·6	·34	5·9	25 000	5	1·0	11·0
1·8	·36	12·5	16 500	4·5	1·2	19·0
2·0	·39	20·0	14 000	4·5	1·5	25·0

The anode impedance is satisfactorily low, being 16 000 ohms at the rated filament voltage of 1·8. Curiously, the μ *fell* at 1·4 volts, instead of rising as is usually the case. The rather low "power amplification" is, of course, due to the rather low μ of 4·5. The filament efficiency $\left(\frac{\text{output mA}}{\text{input watts}}\right)$ is quite exceptionally high for this type of filament, there being quite enough power to handle a small loud-speaker without distortion, always providing the valve gives a satisfactory life on full power.

From the grid current curves it will be seen that the grid should be maintained below —0·5 volt for amplification, even on the most positive part of its swing.

The D.F.A. 3.

This is a type of valve which we have not previously tested. The grid and anode are (as far as one can see through the flashing) similar to those of the well-known D.F.A. 0 and 1, but the filament is rated to take 60mA at 6V.

As usual with 5·5V or 6V valves, we tested at 4·5, 5, 5·5 and 6 volts on the filament. We found, in our particular sample, that the filament current was about 50 per cent. above its rating, ranging from ·092 to ·105 amp. This, however, did not strike us as important in view of the very great filament efficiency. For the output is really surprising, reaching no less than 40mA, with a "filament efficiency" practically twice that of any other valve we have yet tested.

In this connection there is one quite important point: what is the filament current? It must be remembered that the anode current (treating it as a *positive* current), comes from the anode to all parts of the filament, but is led away back from one point; it therefore passes in part through the filament. What the exact current distribution is depends on many factors, but often one small part of the filament will carry the whole, and where, as in this case, the emission is comparable with the filament current, part of the filament may be seriously overheated if the valve is used carelessly. For this reason, although the valve has a saturation current of 40mA, we should consider 20mA as the maximum *safe* load.

Fil. Volts. E_f	Fil. Cur. I_f	Sat. Plate Cur. I_s	Anode Imped-ance. R_a	Voltage Ampli. μ	Power Ampli. P $\left(=\frac{1\,000\mu^2}{R_a}\right)$	Filament Efficiency. F $\left(=\frac{I_s}{\text{Watts.}}\right)$
4·5	·092	14	13 000	6·5	3·5	36
5·0	·096	21	10 000	5·0	2·5	43
5·5	·101	30	8 000	4·0	2·0	55
6·0	·105	40	6 500	3·8	1·8	64

It may be this that causes several curious points in performance. As our curves show, the valve does not answer markedly to increased filament heat, the four curves lying very close together. Also, the change produced by a given grid voltage was practically constant, while the μ varied in proportion to the impedance.

Altogether a very interesting valve: the grid current curve shows that the grid should always be below —1 volt.

(*For characteristic curves see p.* 280.)

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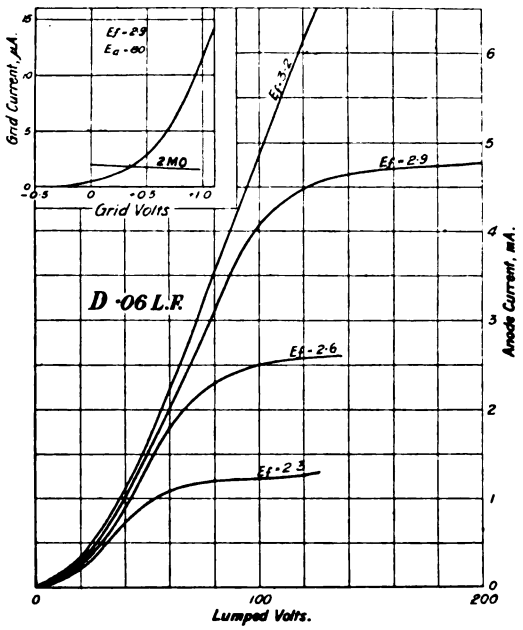

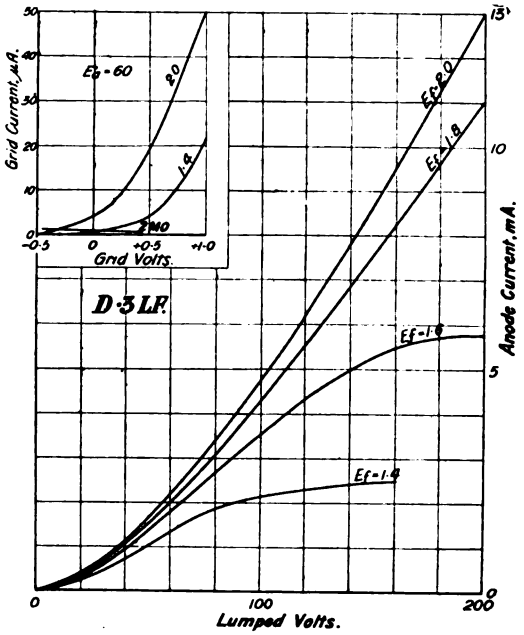

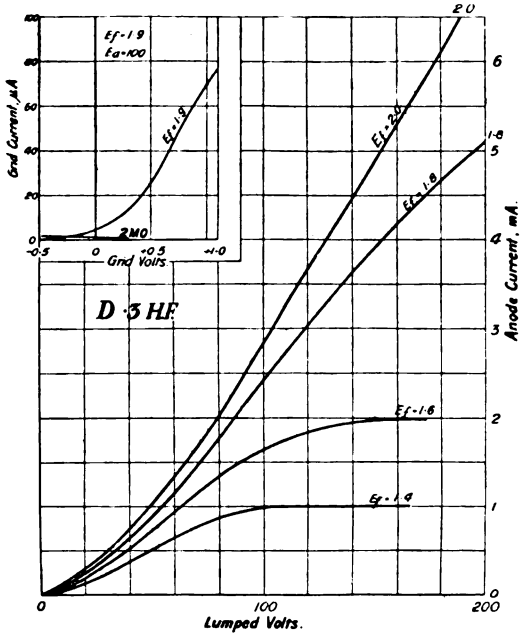

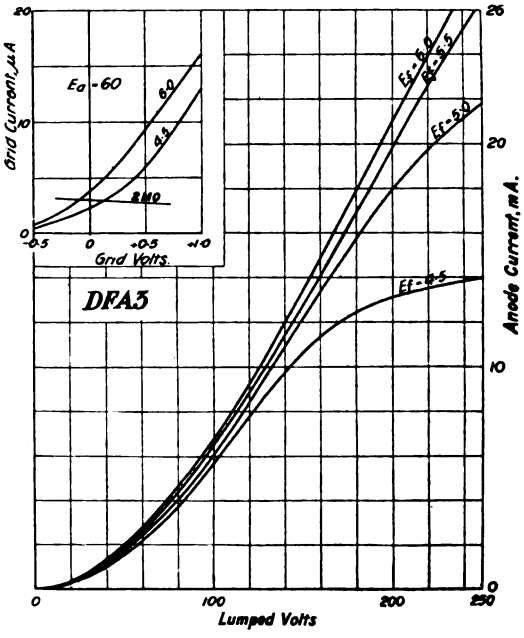

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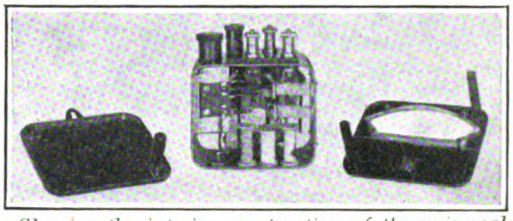
A Useful Range of Meters. [R205·09

WE have recently seen some very interesting small ammeters and voltmeters made by Messrs. Ernest Turner, at Chiltern Works, 53/73, Totteridge Avenue, High Wycombe, Bucks. These are of the type of apparatus which is particularly useful forthe serious experimenter, in that they are at the same time small, accurate and fairly reasonable in price.

One of the features of this series of instruments is the universal set, of which large numbers have been supplied to the General Post Office. We illustrate the complete instrument, and also its appearance dismantled. Taking first the movement itself, this is of the highest class, the pivots working in jewels. The current required to give full deflection on the movement unshunted is 10 milliamps, and the resistance 10 ohms. By the use of alternative terminals, shunts can be put across the movement so that the instrument serves as an ammeter reading either 50 milliamps or 500, and by the use of the switch shown at the right on top of the instrument, series resistances can be thrown in so that it will read either 5 or 50 volts, the total resistance being 500 ohms as a 5-volt meter, and 5 000 ohms as a 50-volt meter. The resistance as an ammeter is 2 ohms when measuring up to 50 milliamps, and ·2 ohms when measuring up to 500. The instrument is priced at £6 10s. If a wider range of measurement is desired, this can easily be obtained at extra cost.

Standard shunts for outside connection are available to read 5 amps or other values up to 50 amps. Our illustrations show 5 amp and 25 amp shunts. Again, external series resistances are available in the particularly ingenious form shown in another of our illustrations. These "resistance pots," as they are called, are arranged to screw on to the voltmeter terminal, and receive the outside connection on their own upper end. They can also be screwed one into another, and can be obtained to add either 50 volts or 100 volts to the normal full scale reading. Thus with two of the 100-volt "pots," the total reading becomes 250 volts, other readings being, of course, in proportion. An important point made by the makers is that the instruments themselves are so carefully standardised that shunts can be supplied from stock which are usable with any instrument; there is no necessity to calibrate the shunts with the particular instrument with which they are to be used.

Another interesting line of meters is a series of thermo-ammeters suitable for high frequency work. They are a combination of thermo-couple and moving-coil milliammeter, and are made in various ranges from ·5 amps to 12 amps. They are guaranteed to be correct within 1 per cent. and to stand 50 per cent. overload; the cost varies with the range, but is in the neighbourhood of £5.



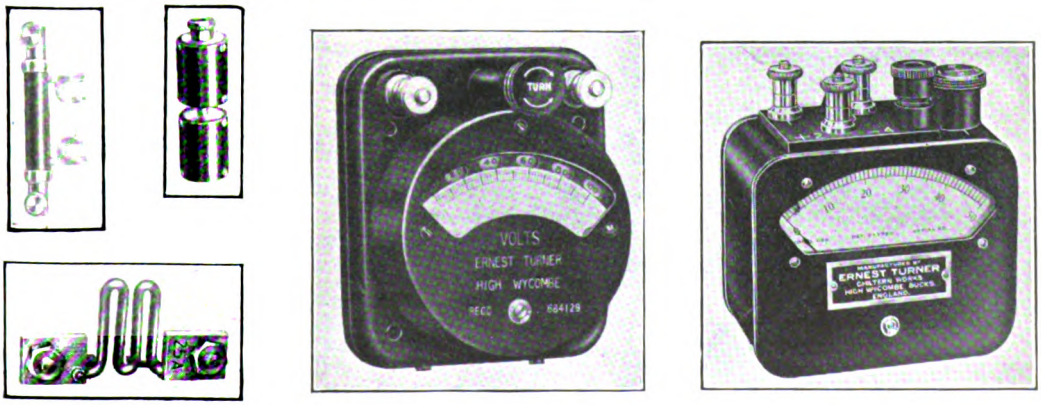
Showing the interior construction of the universal set described here.

In addition to these instruments, there is a complete series of single range ammeters and voltmeters giving full deflection for anything between 5 milliamps and 20 amps, or 15 millivolts and 100 volts. All have zero correctors, and are individually calibrated and guaranteed correct within 1 per cent. Their prices are in the neighbourhood of £2 10s.

Lastly, we might mention one particularly ingenious two-range voltmeter in which the range is changed from 10 volts to 100 volts by a switch, which simultaneously changes the actual figures on the scale. These are made as standard in the following ranges:—

5 and 50, and 10 and 100 volts; or
10 and 100, and 50 and 500 milliamps.

They were originally designed, we believe, for Post Office use, but should be extremely useful for wireless purposes.



Above we show the standardised series and shunt resistances used with the Turner meters, also the double-range and multiple-range instruments described.

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A Good Grid-Leak & some other Components.

IN view of the general opinion that it is difficult to find a variable grid-leak or anode resistance which shall be reasonably constant, considerable interest attaches to the report of recent tests made by the National Physical Laboratory on a series of six Bretwood leaks. We believe that facsimile copies of the N.P.L. report are available from the makers of the leaks, Messrs. Radio Improvements, Ltd., of 95, Great Portland Street, but owing to the demands on our space, we can only give a few of the more important results.

The first test made was to check the resistance of each leak for various numbers of turns from the fully screwed in position. The results are shown on the curves herewith, in which it will be seen that although there is a fairly large variation between individual leaks, they all showed thoroughly even curves with practically no irregularity. It is stated that the results obtained while unscrewing agreed

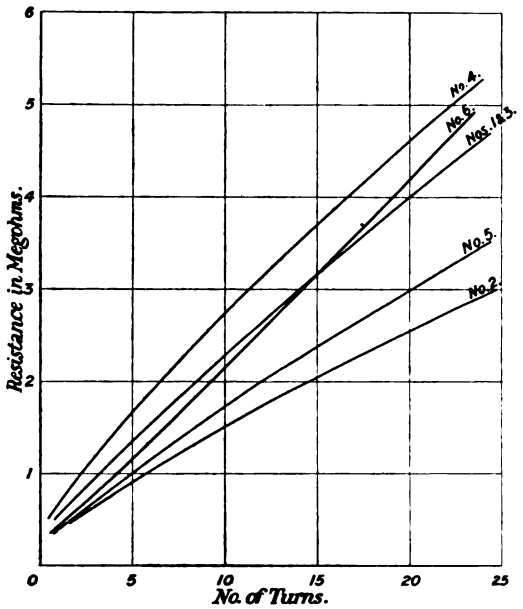

Fig. 1. *Curves showing the remarkably regular variations in resistance of the grid-leaks.*

reasonably closely with those obtained when screwing up. The next test was to measure the resistance of three of the leaks, at one turn, 12 and 24 turns, every day for a week, and again after 7 weeks and 15 weeks. The results were extremely good for apparatus of this type. For example, in one case, No. 3 leak unscrewed 24 turns varied between 5·0 and 5·9 megohms; at 12 turns, between 2·3 and 2·8. The curious point here was that all three leaks gradually increased in resistance during the first week, and went back to their normal values at 7 and 15 weeks.

The third test was to see how constant the resistance was when the leak was left at a fixed adjustment. The three leaks were tested as in the former test, every day for a week, and then after 7 and 15 weeks, at 12 turns from the screwed-in position. The results were that one leak varied between 2·9 and 3·3, another between 1·7 and 1·8, and the third between 2·7 and 3. Altogether the results may be considered quite exceptional for resistances of this nature.

It will be remembered that the company also manufacture anode resistances of the same type, having a resistance varying from 0 to ½ megohm. No N.P.L. results are available for these, but we might state that we have used them considerably

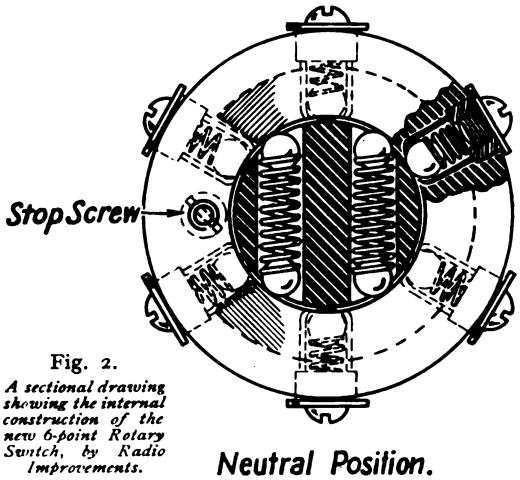

Fig. 2. *A sectional drawing showing the internal construction of the new 6-point Rotary Switch, by Radio Improvements.*

in our laboratory when we have happened to want resistances of a few hundred thousand ohms, and rough tests have shown them to be of the same fine quality as the leaks.

The company have also introduced some other accessories which should be distinctly useful to the experimenter. Their patent valve holder, of which the construction is shown in our sketch, has the advantage of making a very definite contact even where the valve legs are not absolutely standard, and at the same time appears to have a low capacity, although this is not a matter which we have actually tested. The same ball plunger principle is made use of in an ingenious six-point circular switch, which can be used either as a reversing, series-parallel or dead-end switch, and also for other purposes. As will be seen from our illustration, this is very compact

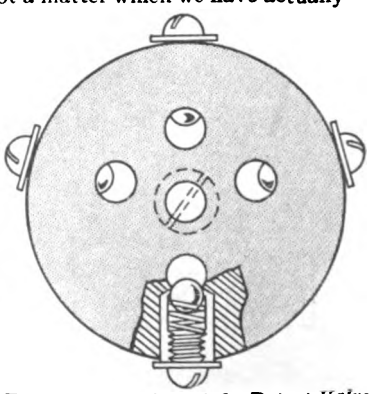

Fig. 3. *A section of the Patent Valve Holder by this Company.*

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Power Amplification for Loud-Speakers used at Wembley.

By Ernest W. Braendle. **[R542 : R587**

(*Research Dept., Metropolitan-Vickers Electrical Co., Ltd.*)

A description of apparatus used and work accomplished against abnormal difficulties.

IN view of the large amount of wireless work which was carried out at the British Empire Exhibition, it will no doubt interest readers to be given some idea of the apparatus and magnitude of the work involved.

One may say that there were three main attempts to meet the public demand in this direction, namely, the Western Electric Public Address System, which transmitted music, etc., throughout the grounds; the British Broadcasting Company's simultaneous broadcast of the "Wembley Half-Hour" and the loud-speaker system installed by Messrs. Vickers on the outside of the Palace of Engineering, for the purpose of giving the public the time as chimed from the belfry adjoining the Research Section. It is with the last-named that I propose to deal, although I have no doubt that some of my remarks apply equally well to the others, particularly with regard to the great difficulties that had to be overcome. In order to avoid confusion, it is as well to point out here that the British Broadcasting Company, when transmitting the Vickers' carillon from Wembley, employed their own apparatus entirely.

The apparatus used by Messrs. Vickers (see Fig. 1) consisted of a small 20-watt transmitter, which enabled the chimes to be heard at Vickers House, Westminster; a five-valve receiver for the reception of broadcasting and supplying music to the private roof-garden on top of the Research Section; a magnetophone and five stages of power amplification, which either modulated the transmitter or supplied current to the loud-speakers. Both the transmitter and receiver being of the normal type, there is no need to deal further with them here, and it is therefore to the modulation and loud-speaker system that I am devoting my space.

The magnetophone was of a type developed for broadcasting purposes by the Metropolitan-Vickers Electrical Company, Ltd. The particular instrument employed at Wembley was actually in use for several months at the original Manchester Broadcasting Station (2ZY), and a similar magnetophone was used

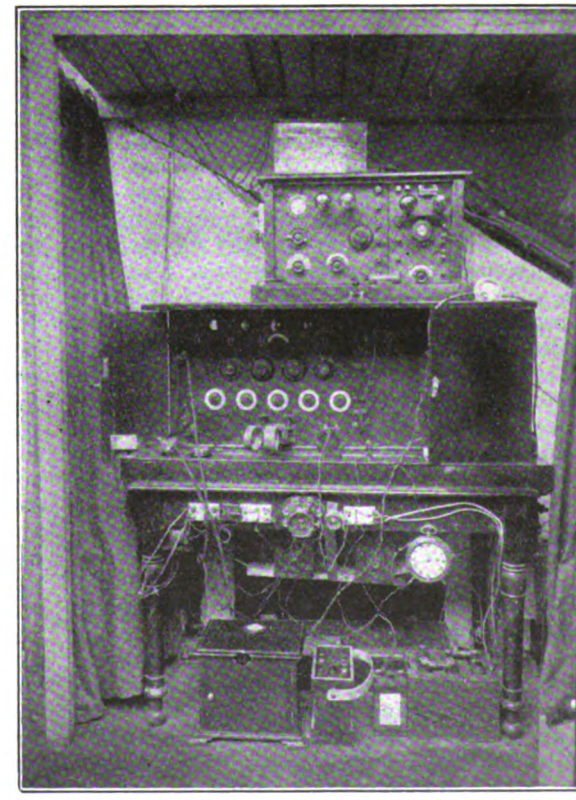

Fig. 1, *showing, from top to bottom, the transmitting, receiving and amplifying units of the apparatus used at Wembley. The "control-clock" can be seen in the right-hand bottom corner.*

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for announcement of the KDKA relay tests from the Metropolitan-Vickers Station (2AC).

Anybody who has ever tried to use two or three stages of low-frequency amplification will appreciate the difficulties involved in obtaining reasonably distortionless amplification combined with freedom from self-oscillation—although it may here be remarked with advantage that the former is not infrequently due to the latter, which may be taking place at a frequency above the audible range of the listener.

Now, the average serious experimenter is usually content when he has amplified a signal just audible in the phones to a strength, we will say, suitable for a large room—or perhaps the garden—in his own home, where interference and line-capacity troubles are almost negligible. In the case of the amplifier in question, however, the smallest number of amplification stages had to be found which would suitably raise an input of three or four micro-volts from the magnetophone to a power capable of producing sufficient sound to flood some hundreds of acres of ground, over which there already existed a considerable volume of sound. After a large amount of experimental work, five transformer-coupled stages were decided on, the first four being supplied from the same high and low tension supply. The last stage had its own low tension and a supply from the transmitting generator of 500 volts high tension passing 40 milliamps—that is to say, the last stage alone was passing approximately 20 watts, a power equal to that taken by the transmitter.

As may be imagined, to obtain this the amplification efficiency had to be fairly high, and it is worthy of note that the only damping used for stabilising was a ·025 mfd. condenser on the input to the last stage, which had the effect of reducing the output by 3 to 5 per cent.

Having finally obtained a suitable system of amplification for the loud-speakers—the lead-covered leads to which required nearly 1 000 yards of cable—and having overcome the difficulties involved in making that system suitable for modulating the transmitter when required, attention was next directed to the relative positions of the source of sound and its pick-up—in the shape of the magnetophone.

In a broadcasting studio nearly all the sounds to be transmitted are, comparatively speaking, highly damped, and this damping is further accentuated by the prevention of echo by wall damping in the studio itself. In the case under discussion, however, the sounds to be dealt with were derived from a peal of bells, some of which, once struck, could be heard ringing for ten seconds or more, producing complete chaos of sound. Besides this trouble, the bell-chamber was utterly devoid of any form of damping, and in consequence did more to accentuate the effect of one note slurring into the other than otherwise. Unfortunately, the large volume of outside noise in the Engineering Hall made attempts at picking-up anywhere other than in the bell-chamber quite out of the question. Despite this handicap, a position in the bell-chamber was decided on, the magnetophone was adjusted to operate with very high damping, and was suspended by rubber hangings to prevent wall vibration from taking effect.

Two main factors had to be taken into account in the positions chosen for the loud-speakers—namely, positions most suitable from a technical point of view ; and positions to which the Exhibition authorities would agree, great care having to be taken that the general architectural outline of the building should not be affected.

With these points in view, two large "Leviathan" Amplion loud-speakers were mounted on special platforms on the roof some twenty feet back from the parapet, one on either side of the south entrance, overlooking the lake and pointing S.E. and S.W. Two others were mounted immediately beneath the roof on the western face of the building.

From this it will be seen that, given sufficient power, the whole area facing the southern and western sides of the building could be covered fairly evenly, although, actually, the two over the south entrance appeared to have more directional effect than might be desired, owing to the fact that the sounds were not merged, as was the case with those on the western face. Another point of interest arose in respect of these positions in the fact that, although the loud-speakers were connected in series, and were therefore being supplied with the same current, those under cover on the western side were apparently from four to five times as powerful as those on the south, due to the screening effect of the roof of the colonnade. This had to be balanced by shunting the leads to the loud-speakers on the western

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side with a fairly high resistance, which, while reducing the current in these, slightly increased that available for those on the south side.

One of the most astonishing features was the effect the presence of the general public in the grounds had on the sound—an effect which may be divided into two headings: (*a*) increase in the threshold of sound, and (*b*) actual sound damping due to the continual breaking of reflecting surfaces.

It was essential during all the earlier tests that these should be made either on a Sunday, or some other time when the public were not present, and therefore due allowance had to be made. This was done, and some 40 per cent. for the former and 10 per cent. for the latter was allowed, which, when tried out, was found to be far from sufficient. In fact, it was necessary to double the then existing output before the volume of sound was anything like satisfactory.

As may be imagined, the loud-speaker system being used almost exclusively for the ringing of the hours, half-hours and quarter-hours, it was not a practical proposition to have a man continually present to switch on the apparatus, neither could it be left running for any length of time without attention. It was therefore necessary to devise some method whereby the whole apparatus, including the high-tension generator, could be automatically switched on every quarter of an hour for just sufficient time to ensure the satisfactory recording of the chimes. It was also found important that when the ordinary broadcast receiver was being used, it had to be switched off for the period during which the amplifiers were in use, as the magnetic coupling between the two was sufficient to allow the received signal to make nearly as much noise as the bells themselves. For this purpose a system (shown diagrammatically in Fig. 2) was developed which depended entirely on a contact made by the rotating minute hand of an ordinary clock, in connection with the necessary relays for its control.

From Fig. 2 the sequence of events can easily be followed. On contact being made by the clock, current was allowed to flow through the filament of the valve of the last stage of amplification, and also through the exciting magnets of the two relays, which in turn lit the filaments for the first

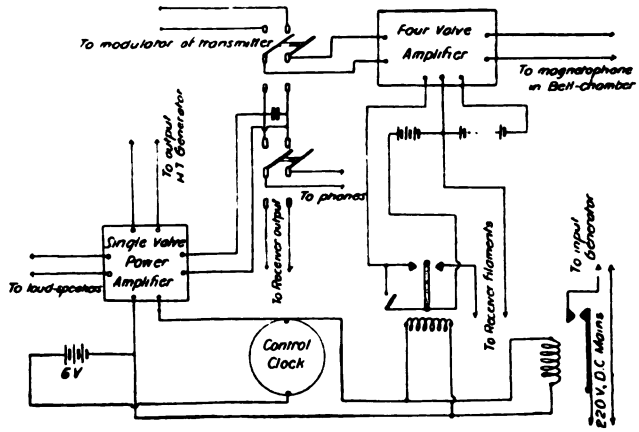

Fig. 2.
A diagram of the Wembley apparatus.

four stages of amplification and also started up the high-tension generator. (It will be noticed that the relay for the valve filaments had two contacts, one at normal and one when excited, the former being connected to the broadcast receiver valve filaments, which were thus disconnected when the amplifier was in action.)

It will also be seen when examining the connections to the double-throw switches that it was necessary to disconnect the last stage from the first four stages of amplification in order to connect the latter to the wireless transmitter. This prevented any tests, etc., which may have been made with the transmitter from being put out on to the loud speakers.

In conclusion I would like to say that, although many difficulties were met with, many of these were considerably lightened by the courtesy and generosity of the stand-holders, who were good enough to lend apparatus.

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Long Distance Work.

By Hugh N. Ryan (5BV). **[R009-2**

SOME four years ago, the amateurs of Europe, America and Australasia set out to make the whole world their range, and now, to all intents and purposes, they have succeeded. The tasks immediately before them are to "polish off" the few countries still not in touch with the rest, and to organise themselves internationally on such questions as wave-lengths and working schedules, so that they may use to the best advantage the results they have obtained.

The two places with whom we should soon be in regular communication are South America and South Africa. Signals from Argentina, Chile and Mexico are now quite often heard in England, and at least three of our stations have been heard in one or more of these countries, so no difficulty should be experienced in communicating, beyond the usual initial trouble of getting used to each other's time and wave-length.

South Africa presents a somewhat harder task. We understand that there are many keen amateurs there, but we have very little information as to their transmitting activities. (Perhaps some South African reader of these notes will let me have full information ?) At any rate, we gather that they are not yet well established on the shorter waves, as a whole, but no doubt they will be soon when communication with them should be easy enough. As far as I know, 2SH is the only British station who has been heard as yet in South Africa, though a number of us were heard in Northern Africa over a year ago.

The only other part of the world then left will be Asia. Amateur radio is quite active in Japan, and we may soon expect reports on our signals from there, while Japanese signals have already been reported in this country, though the reception is not yet confirmed. Many of our stations have been heard in the more westerly parts of Asia, and many have worked with a station in Mesopotamia.

The only remaining "blind spot" in Europe is now filled by the starting-up of a Czecheslovakian amateur, at a place with the exciting name of Plzen (a name, I think, more readily transmitted by a key than a microphone). His call sign is OK1.

The New Zealand and Australian signals have entirely disappeared for the present, and British stations have been occupied almost entirely in working Americans and a few (surprisingly few) Canadians. During most of the past month American signals have been very profuse indeed on the 75-80 metre band of wave-lengths, and a number of our stations, working between 90 and 100 metres, have been very successful in communicating with them, though recently (since about the first week in January) there has been a considerable falling off in the number of American signals.

Strangely enough, the Americans who are still heard are of good strength, so it would appear that the decrease in signals heard is due to less transmission in America rather than to bad atmospheric conditions.

The earlier half of the second week in January was notable for the great increase in QRN, which culminated on the morning of January 10, when it made American work almost impossible. It is curious to note that at midnight the same day (if one may so express it) there was a complete absence of QRN, and the signals of Canadian 1AR were stronger than I have heard them since last January and February.

The star stations in transatlantic work, judged by the number of Americans worked, are 2KF, 5LF, 5NN, 6LJ and 6NF. (I have not included 2OD, as I don't know how many he has worked ; but, of course, he can work every American he hears—and he hears more than most of us.)

A number of our stations, though they have not worked such a large number of Americans as those just mentioned, have done some very good work in this direction. These include 5SZ, 6VP, 6XG and several

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others who have only recently connected with America, but are doing their best to make up for lost time. 5QV, hitherto better known as a telephony station, has worked American 1CMP. His telephony also reaches out exceptionally well. 2TO, who appears to be the only other DX station in the Eastern Counties, is not working for a time, his mast having blown down.

In the west 6RY is apparently keeping the "good work" going, though I don't hear much from him.

5SI, who, since the departure of 5KO has shared with 6RY the job of keeping DX alive in the west, has unfortunately been ill during practically the whole DX season, and is not yet back "on the air." Before his illness he worked a number of Americans and Canadians on powers below 15 watts. 2UV, of London, another of our well-known men, has also had the bad luck to be ill just when he most wanted to work.

There are so many stations now in London that I must necessarily report their work very briefly, or else they will occupy most of the article.

2KF, 2NM, 2OD and 5LF need not be reported upon at all. The number of stations they work depends only on the number they call—everyone hears them. They have all worked some 50 or more Americans and Canadians this month. 2KF has also been heard in Indo-China.

2SH has just made the amazing discovery that, though he has had a perfectly-good rectifier, with two 250-watt rectifying valves, running for many months, he had apparently forgotten to connect it up, so he has been feeding the set with raw A.C., with the rectifier merrily lit up—doing nothing!

In spite of this, he has been covering some good distances, and claims a number of records supposedly held by other people. He apparently was the first British amateur heard in America, having two confirmed reports previous to that upon which 2JF's claim to the honour rested, so 2JF would appear to be the second, and not the first.

2SH has also a confirmed report from Iowa, U.S.A., where his signals were heard when it was daylight nearly the whole way across, thus beating 8AB's daylight record (established on 32 metres). He heard several Mexicans before 5NN (who was thought to be the first to do so), has been received in Johannesburg, and worked an enormous number of Yanks and two New Zealanders; and, finally, one of his valves, presumably feeling the strain of such a record-breaking season, has gone soft.

2DX is steadily working Americans, with a master oscillator and a superheterodyne. He has worked nearly every district in U.S.A. 6NF is devoting himself almost entirely to transatlantic work, though he has also worked the station in Mesopotamia. He has worked over 50 Americans, including 5CN, who is thus one of the first American "Fives" to connect with this country.

6LJ has worked some 35 Americans, as well as Mosul. He has been heard by New Zealand 4AB, and has heard Australian 3BD, in addition to two Mexicans and 1083 Yanks. He starts hearing Yanks at 6.30 p.m. and loses them about the following mid-day! 6XG has worked American 1BHM, with 10 watts input to a D.E. receiving valve, although jammed by an 80 kilowatt station on the other side.

5NN is rapidly becoming (if he has not already become) one of the longest range stations in the country. He has been heard on the Pacific coast of America, and in Argentina and Africa. Five New Zealanders have heard him, and he has worked three of them. All reports say he is the strongest and steadiest station ever heard, but one seems to find that foreign reports say that about most of us. I hope we all deserve it as much as 5NN!

6QB has increased his input from 3½ watts to 4 watts, but in spite of this enormous power he seems to have done better work with the receiver than the transmitter this month, having heard several American "Sixes" and a Mexican.

5BV has done very little, since as soon as the new transmitter was finished it christened itself by blowing all its condensers (including some borrowed from 2ZT), and then sending two 150 watters soft. An expensive christening. However, the transmitter appears to be a success, apart from these little troubles, since, when it was coaxed into action for a few days, its signals were reported to be very strong everywhere, including America and Czechoslovakia. Some very successful daylight work was also carried out with Danish 7QF. By the time these notes appear 5BV should be working regularly again.

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That concludes the activities in London itself, but two stations a short way out, 6VP and 6UV, have been doing good work. The former has worked seven Americans and Canadians. While he was working Canadian 1AR on Christmas Day he wished him the compliments of the season, and received the following reply: "SAME TO U OM, FROM ENGLISHMAN HI! (Pause for filling glass.) NW DRINKING UR HEALTH, OM, HERE'S TO U. . . . NW DRINKING HEALTH TO ENGLAND, GOD BLESS HER." An excellent sentiment, but a little rough, I think, on the "dry" Americans listening!

6UV is a newcomer to DX, but he is already heard everywhere within 1 500 miles or so, and has received Australia and New Zealand.

In the Isle of Wight 5TZ appears to have the air to himself. He has been working on both 10 and 50 watts, but so far has had little success with the latter. On 10 watts he reaches Finland, Italy, Scandinavia and Czechoslovakia. He has received four New Zealanders, two Australians, two Mexicans and Argentine DA8.

In Northern England the most active stations are 5MO, 2CC, 2KW, 5SZ and 5DN. The first four are now in regular communication with America, though 2CC has been having generator trouble. 5SZ is new to transatlantic work, but is doing very well at it. He is also doing good work with Italy and other European countries.

5DN has been carrying out some low power schedule tests with America, but has not yet heard the results. He has also worked French 8BV with 2·5 watts input.

So much for England. My note on the lack of activity in Scotland has brought forth a number of letters, which show that 2OA is far from being the only station working there. I have discovered eight stations so far, but apparently only three of these (2OA, 2TF and 2MG) are at present engaged in short-wave DX. My failure to hear the others last month is evidently due to the fact that they work on the longer waves (above 110 metres).

2OA has been ill, but has worked Canadian 1AR. 2MG has worked Finland and Switzerland, the latter on telephony, and received Australian 3BQ very strongly. He is not working at present, owing to valve trouble, but will be on again soon.

I have three reports from Ireland, two of which are from the Free State, in response to last month's appeal. Mr. Neill, of Co. Antrim, hears about 50 Americans and Canadians every Sunday morning, and has heard three Australians.

The two Free State reports are from Mr. McCormick, of Dublin, and Mr. Goldsbrough, of Fethard, Co. Tipperary. Mr. McCormick works chiefly in co-operation with 2ZK, 2VF, 6NI and 2II, all of Liverpool, but he also receives telephony from a number of other English stations. Mr. Goldsbrough listens more for morse stations, and has sent me a very long list of stations heard, which includes most of the well-known stations in Europe, and one Canadian.

British work has taken up so much space this month that I can only review Continental activities very briefly.

The two most interesting events are the entries of Denmark and Holland into the list of countries now in touch with America. The leading amateurs of each country have now worked across the Atlantic (Danish 7EC, 7ZM, 7QF and Belgian P2, W2).

I have just heard from Belgian 4C2 that he has been unable to join in the work owing to illness, and that a gale has just carried away all their aerials. Bad luck!

For some years we have been hearing two Swiss stations (XY and XZ) at very irregular intervals, but recently quite a number of Swiss stations have appeared, with call signs beginning with the numeral 9. 9BL is the strongest of these, and I have had several conversations with him.

That concludes the report, but a number of my correspondents have asked me to raise the question of the serious jamming of American stations by Frenchmen using raw A.C. supply. They do not, of course, realise the trouble they are causing us, but if this should catch their eye, might I ask them to move their wave-lengths up 10 or 15 metres, or else to smooth their supplies, preferably the former? It would be better for all concerned if Europe kept the 75-85 metre band quite clear during transatlantic hours. All other countries are now doing this, and our French friends will be helping us very much if they will do the same.

The Americans are listening for Europe on 85 to 110 metres, where there is less jamming from their own stations.

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The M-L Anode Converter. [R355·2·009

A description of some interesting converters which are being made for either transmission or reception.

WE have received for test two types of the "Anode Converters" made by the M-L Magneto Syndicate, Ltd., of Coventry. The purpose of these converters is to provide a high-tension D.C. supply, the primary source of power being an accumulator. The machine is made in four types :—

A	6 volts to	66 volts.		
B	6	,,	,, 105	,,
C	12	,,	,, 295	,,
D	12	,,	,, 530	,,

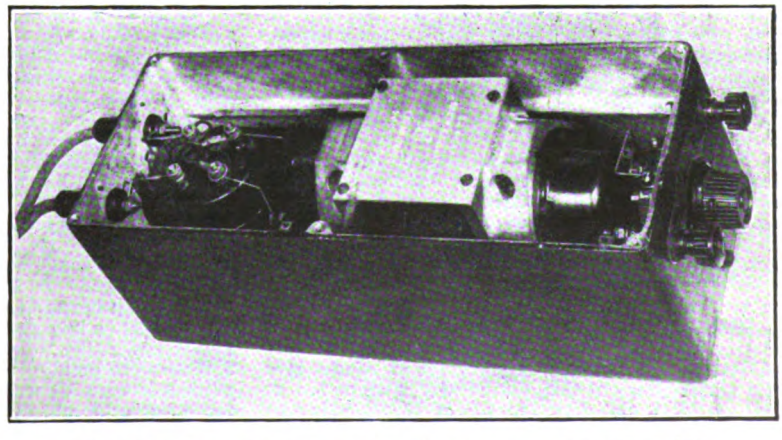
These voltages are on the full output load of 20mA ; at no load the voltage is about 30 per cent. higher. The machines sent were the B and D types. In general design they are similar.

The converter consists essentially of a small motor-generator having an armature which carries two commutators and two separate windings. In order to minimise ripple the number of commutator segments and armature poles is made larger than is usual in such small machines. Permanent field magnets of cobalt steel are used, as this involves a smaller no-load current than would be possible if field windings were used. The rotating part is well balanced, running on ball-bearings, and the machine stands loosely on four rubber buffers, so that when the lid of the case is in place the amount of noise to be heard is inappreciable. The input—and therefore the output—is simply and conveniently controlled by a variable resistance included in series on the low-tension side. A smoothing circuit is provided on the H.T. output side comprising two 1μF condensers and a double choke. The converter, smoothing circuit and control resistance, are all contained in a case which appears to be of cast aluminium. The overall dimensions of the whole apparatus are: length, 15 in.; width, 4¾ in.; height, 5 in.; weight, 14½ lbs. It has therefore a great deal to commend it where compactness or portability is required.

As for the actual results of our tests, the D Type Anode Converter appears to do everything which is claimed for it by the makers. It gives satisfying results on 10 watt C.W. transmission, and the amount of hum to be detected in the carrier-wave is a negligible quantity provided the machine is in proper adjustment and is not overloaded. It might be mentioned here that the particular machine we have tested did not work properly when we first tried it, the running being irregular and the output having a bad ripple. It was some time before we discovered the cause of the trouble which proved merely to be that one of the L.T. input brushes fitted rather too tightly in its holder and was not adapting itself properly to the commutator. This was remedied by filing down the copper-carbon brush slightly to enable it to slide more freely in its holder. This small attention removed the trouble referred to and the machine ran very steadily, giving a smooth output.

The makers supply a curve-sheet (reproduced) showing the relation between input L.T. current and H.T. volts and milliamps output. When there is no load on the H.T. output the input current is just about 1.3 amp while the input on full load (12 watts) is about 2·5 amps. The efficiency on full load is 44 per cent., which is good for so small a machine.

There are one or two minor criticisms which may be passed. For one thing we do not consider an output of 25mA quite sufficiently liberal even for a 10 watt transmitter. There is no latitude for a satisfactory choke-control set, as the current supplied to the control valve should be at least equal to that in the oscillator, and this at once involves an input of at least 20 watts. Then again a certain margin of safety is desirable in both experimental and routine work. For instance, one's oscillator valve may cease to oscillate, an occurrence which not infrequently results in a



An internal view of the converter, which gives an impression of its extremely compact construction.

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large overload on the H.T. supply. The large variation of H.T. voltage with load which the converter shows is a disadvantage in some ways. Thus we found it unsatisfactory to key a transmitter by breaking the H.T. supply to the anode, or, for that matter, in any manner which makes a large change in the load, as the generator races when the key is up, causing an increase in voltage which falls off rapidly when the key is again depressed. This is hardly conducive to a steady C.W. note. The input control resistance, which is made on the lines of an ordinary filament resistance, seems a little flimsy for the job and gets rather hot near full load; once we noticed it smoking slightly.

The machine is very nicely constructed, and should be a most useful piece of apparatus to those who can afford it. The latter point, we might hint, will prove the stumbling block where many experimenters are concerned, as the D-Type Anode Converter is priced at £18. It would, perhaps, have been happier if the makers had allowed a rather higher power rating, say, 30 watts at 500 volts.

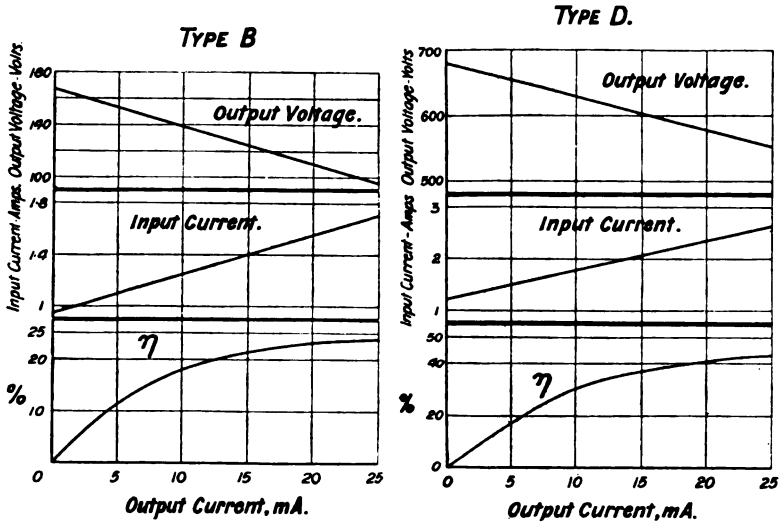
This, of course, would very likely involve an input power too large for easy handling by such accumulators as the amateur usually possesses, and there would appear to be distinct possibilities in a similar machine to run off D.C. mains. The company supply a generator giving 30mA at 500 V for mechanical drive, but this again seems to us hardly sufficient.

With regard to the B-Type instrument (160 to 105 volts), the basis of criticism is naturally different. The curves in our second figure give the performance of this, and it will be seen that at full speed it gives 170 to 100 volts according to load, with an input of 1 to 1·7 amps at 6 volts and an efficiency of 25 per cent. at full load. In actual practice we used it mostly on about 6mA load, with some of the regulating resistance in, and it then took about 1·3 amps.

The important point for receiving purposes is, of course, silence. Some most interesting points are brought about in the makers' excellent leaflet. Among these is the fact that while the output smoother is sufficient, there is the possibility of imposing a ripple on the supply, which might give trouble if the generator is fed from the filament battery. However, a special low-resistance choke is provided as an extra to avoid this, and we found it most effective. When feeding the last valve (a power valve of the 6V ·25A type) the hum was not audible from the loud-speaker even in silence, though it was there in the phones. Even here it was not enough to interfere with signals of comfortable strength.

When running at or near full speed there was so little mechanical noise that on one occasion we forgot it when shutting down and let it run all night; but there is a critical speed—just over half speed in our sample—at which there is a distinct noise.

To meet the need for supplying valves at different voltages, a series resistance box is available which gives 60-80 volts when the full output is about 140. This is inductively wound, and acts as an extra smoother for the earlier stages—an important point, for any hum here is, of course, amplified.



These curves afford a means of judging the efficiency of the two types of converter tested.

We have made an estimate of the comparative cost of feeding a set from the generator or batteries, and there is no doubt that the generator is more expensive for a set such as our own taking 5 to 8 mA. But it has some important advantages. The voltage can be sweetly regulated without the interruption caused by plugging: and it is entirely free from the scratchings of an old dry battery. For demonstration work needing 15 or 20mA it is much more portable, with its accumulator, than big batteries. From the general design of the generator itself we should put its life at about twice that of a magneto—say 25 years.

Unfortunately it is not, and can never be, a really cheap instrument: the type B costs £11 5s., the resistance box £2 15s., and the extra primary choke 10s. But we should not hesitate to install it if we were building a set where reliability and convenience were desired, and extra cost could be faced with this object.

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Increasing the Range of D.C. Measuring Instruments. [R250

By E. H. W. Banner, M.Sc., A.M.I.R.E.

In the following article the author shows how various commercial electrical measuring instruments can be conveniently and cheaply adapted to meet the needs of those engaged in serious experimental work.

THIS article gives the principles underlying the change of range of various classes of instrument. It is not constructional, but gives the theory and calculations for application to any instrument, not one in particular.

Certain converted instruments are described as examples.

Classification.

There are various means of classifying measuring instruments. For the purpose of this article they can all be classed into one of two groups—Portable and Switchboard instruments.

The former are usually wood-cased instruments, and are not intended for permanent inclusion in a circuit but for general use in different circuits. The latter are almost always connected in a particular circuit permanently.

For all-round use a portable instrument should therefore have an infinite number of ranges, while a switchboard instrument usually only needs one.

A portable instrument of single range is thus of less scope than one of two or more ranges, but the switchboard instrument permanently in circuit needs no more than its initial range. In certain cases portable instruments are connected permanently to circuits and switchboard type instruments are mounted on stands to be portable. For these cases the class as described above should be reversed. Any instrument acting as a portable instrument, *i.e.*, not permanently included in a circuit, can with advantage have more than one range. The cost of converting a single range instrument, within the limits stated later, is only a few per cent. of the cost of the instrument, and so the addition of several extra ranges will cost less than the cost of the original instrument.

For example. A cell-testing voltmeter reading to 3 volts might be available. The same instrument can be converted to read equally well on, say, 3, 15, 30, 60, 120, etc., volts and so become of greater use to the experimenter.

Definitions.

It is necessary to consider a few definitions here in order to prevent mistakes arising from unaccustomed nomenclature.

A voltmeter or ammeter is an instrument, not a meter. A meter is one that integrates the value of the applied unit, *i.e.*, ampères or watts, with time. Meters, therefore, read in ampère-hours or watt-hours.

The indicator is the instrument proper and includes the moving and fixed systems, together with the pointer and scale. If the whole of the working parts are contained in one case with the indicator it is called a self-contained instrument. In the case of ammeters with external shunts and voltmeters with external resistances the whole combination is the instrument.

Types of Instruments.

As there are several types of instrument in use and the methods of altering the ranges of each are usually different it is necessary to give a brief résumé of the principles of each type likely to be met with.

The types of instrument are these :—

1. Moving coil permanent magnet (d'Arsonval).
2. Moving iron attraction and repulsion types.
3. Thermal expansion and thermo-electric types.
4. Dynamometer.
5. Induction.
6. Electrostatic.

The first two are common and the thermal (hot-wire) instruments are used extensively

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for high frequency work, *i.e.*, the aerial current in transmitters.

The last three are not generally available, being rather more expensive than the others and having a different sphere of application.

The last one, however, the electrostatic instrument, is theoretically the best. If it could be made to be portable and of low range it would have greater application in radio work. It is only possible, however, in high ranges.

The first three will now be dealt with, and the remainder ignored.

Moving Coil Permanent Magnet Instruments.

The moving system consists of a light coil pivoted on its axis, and able to swing in the gap of a permanent magnet.

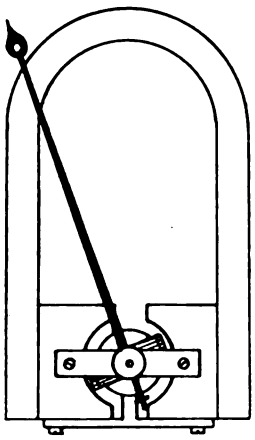

Fig. 1.

One of the two springs constrains the coil to a position as shown in the sketch, Fig. 1, the coil being connected via the springs or extra ligaments to the circuit. A current in the coil tends to rotate the coil in a direction depending on the polarity of the leads, the polarity of the magnet and the direction of winding the coil. An iron core is usually inserted in the space between the sides of the coil for the purpose of maintaining a radial field, and consequently a uniform deflecting force.

At any given temperature the coil has a fixed resistance, and if a certain current is required to produce full-scale deflection, it is seen that by Ohm's Law the voltage drop across the coil is fixed. This fundamental fact is the reason why there is no essential difference between a voltmeter and an ammeter. In a particular case the moving coil of an instrument had a resistance of 5 ohms, and by measurement it was found that 15 milliampères produced full-scale deflection. By Ohm's Law the voltage drop is 75 millivolts, and so with this instrument connected in series, *i.e.*, as an ammeter, its range was 15 milliampères, similarly by connecting in shunt to the circuit, such as measuring the drop across a resistance coil, the range was 75 millivolts.

For the simple instrument described there is no reason why it should be called an ammeter in preference to a voltmeter, and *vice versa*, excepting by the scale. If the scale is calibrated in volts and ampères (or millivolts and milliampères) a volt-ammeter is available. Fig. 2 (*a*) shows the connection as a milliammeter and (*b*) as a millivoltmeter.

Moving coil instruments, by using a permanent magnet, are "polarised." That is, they will reverse their direction of rotation with reverse of polarity of the supply.

This makes them unsuitable for alternating currents, but for D.C. they are almost ideal. The fact of their being polarised makes them available as central zero instruments when required.

Moving Iron Instruments.

This is one of the earliest forms of indicating instruments and is used extensively for alternating current circuits. On direct current it is not so good as the moving coil type, but it is cheaper, and so used to some extent where the highest accuracy is not necessary. The construction is usually a bobbin of wire or strip metal and in the attraction type a piece of soft iron pivoted so that it is attracted into the centre of the bobbin when the coil is excited.

The repulsion type has two small pieces of iron, one fixed and one pivoted. When a current is passed through the winding the two irons become similarly magnetised and repulsion ensues. The pointer is arranged to indicate on a calibrated scale in both types. There is no difference in the alteration of range for the two types. Both are electrically similar. This type of instrument is very robust and will usually stand a large overload safely. They should be used for low frequency A.C. only, as at high frequency the effect of the high inductance is to increase the apparent resistance so that less current is passed for a given voltage.

The hot-wire ammeter has very small inductance and capacity and so is satisfactory at high frequencies.

Thermal Instruments.

These are frequently employed by experimenters and are of use in transmitters.

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The hot-wire type consists of a wire which carries the current to be measured, the resulting heating increasing the length of the wire. This increase in length, or more commonly, the sag, is arranged to operate a pointer against a control spring.

The thermo-electric instruments are rather more expensive and so are not dealt with. They are marketed by the Weston Electrical Instrument Co. and other firms.

Hot-wire instruments should only be used for high frequency circuits as their consumption of power is high and their overload capacity low.

General Observations on Range Changing.

In the example given on the moving coil instrument it was stated that that particular coil required 15 milliampères (mA) and 75 millivolts (mV) to produce full-scale deflection. This current and voltage requirement is unalterable, and so no lower range is possible. If a range of 150mV is desired, a series resistance equal to that of the coil (5 ohms) must be added. Similarly for any other range. For an ammeter a shunt must be provided which will cause a drop of 75mV across its terminals when the required current is passing. For a low range, resistance of the coil must be taken into account also, but this will be dealt with later.

In general the consumption of power in a moving-coil instrument is less than in a moving-iron instrument of similar range, while a thermal instrument requires far more power. The lowest ranges usually made are as follows :—

Moving coil ..	5mA.	50mV.
Moving iron ..	1 A.	10 V.
Thermal ..	·5A.	2 V.

Moving iron instruments of lower ranges than above are not much more than toys, and are not very reliable, and their power consumption is considerable.

The above figures apply to the usual pivoted instrument, not to more delicate instruments of the galvanometer class.

Possible Ranges.

As previously stated, the minimum range is settled by the winding, and if the instrument is sealed and cannot be opened (such as a Weston sector type instrument of about 4 inches diameter), no lower range than the original can be fitted, although that may be considerably more than the voltage or current required to operate the coil if of moving coil type. Higher ranges, however, can be fitted *ad infinitum* and, if required, without opening the case. Another consideration is the scale fitted. If the range is 10, either volts or ampères, it will be seen that a range of 3 or 30 will not fit the scale, and although another scale could be made or added to the present one, this is not recommended. The ranges available then should be multiples or sub-multiples of 2, 5 or 10, but in the case of a scale which is a multiple of 3, *i.e.*, 3, 15, etc., a factor of 3 is often necessary.

Calibration.

For the purpose of making a satisfactory job of the instrument it is essential that either another instrument of at least as high accuracy is available, or in the case of voltmeters, a Wheatstone Bridge is at hand. For voltmeters it is often sufficiently accurate to measure the resistance added, by a Bridge, and use the instrument, but it is advisable to calibrate with a good instrument if at all possible.

Range Changing.

If the available instrument is of a range which is not wanted and one other range is to be fitted in its place, the matter is simpler than fitting a number of ranges.

Range changing for different classes of instruments will be described in turn.

(1) Moving Coil Voltmeter.

If the required range is higher than that of the scale, measure the resistance of instrument between terminals, if it is not stated

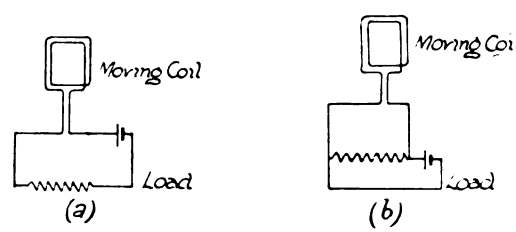

Fig. 2.

on the scale. Call this R_1 and the range V_1.

If the new range is V_2 the added resistance must be

$$\frac{V_2 R_1}{V_1} - R_1$$

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This can be measured on a Bridge, leaving a little extra wire, then after winding the wire can be adjusted to give the current scale reading when calibrated with another instrument. For a required range lower than that pertaining to the scale it is necessary to open the case. The connections will be found to be as follows :—

From one terminal to the coil, from coil to internal resistance, probably wound on bobbins or cards, and then to the other terminal.

It is now necessary to find the pressure drop across the coil when the pointer is fully deflected. This is the value corresponding to the 75mV in the fictitious case considered earlier. In general it will be between 50mV and 1V. Another voltmeter is required for this purpose, unless a milliammeter is used in series, and the drop calculated from Ohm's Law after the resistance has been measured. No lower range than this is possible, but any range between this and the original is available without extra wire. The resistance bobbin may be removed and the new resistance calculated as before, where the resistance of the coil is R_1 and the coil drop is V_1. The original resistance and range are of no consequence. The added resistance must then be inserted in place of the previous resistance.

It can be done by unwinding wire from the bobbin and frequently trying it with the standardising instrument until the reading is correct, *i.e.*, full-scale deflection for the required number of volts.

The resistance wire, and method of winding, etc., will now be stated.

Constructional Details.

The resistance wire can be either manganin or constantan. The former is somewhat better but rather more expensive. The gauge should be about 30 or 32 S.W.G. It may be wound on the existing bobbins if there is room, if not, another bobbin or card will have to be provided. If the required length is in one piece and not too long it is best to double the wire from the centre and to wind on from here, *i.e.*, bifilarly. The two ends are then accessible for connection and final adjustment.

The object of bifilar winding is to make it non-inductive and is desirable. If the added wire is very long and already on a spool, it can be wound on the bobbin by winding one layer, binding the end of the layer with cotton, and winding alternate layers in reversed directions. This latter method is better if the range is a few hundred volts, as in a bifilar winding a high pressure exists between the free ends of the wire, and as these are together the insulation is insufficient and may break down. Shellac varnish should frequently be applied to keep the wire in position and improve the insulation. Any insulation is suitable, but silk covering is best. This additional bobbin can be inside the case, if there is room, or external to it. On calibrating, the scale figures must be altered to their new values, but the scale marks should not be redrawn.

(2) Moving Coil Ammeter.

The ammeter is not quite so simple as the voltmeter, as there is a small resistance in series with the coil, the whole being across the shunt. This series resistance is called the "swamp" and has a resistance of about four times that of the coil. Its purpose is to reduce the temperature error of the instrument, and so it must be left intact. Voltmeters having a series resistance have no separate swamp, as the resistance itself serves this purpose.

For a higher range it is only necessary to add a resistance across the terminals, this may be internal or external, as convenient, but it must be calibrated after fitting, as if external the resistance of the leads will affect the reading.

Measurement of the shunt resistance by a Bridge is not usually satisfactory, as the Bridge method is not reliable below about 1 ohm, and shunts are frequently of less resistance than this. The best means of conversion is therefore by trial. The calculations are as follows :—

A_1=present range.
A_2=new range.
R_1=present resistance of coil and swamp.
R_2=resistance corresponding to range A_2.
R_3=resistance of shunt required.

$$R_2=\frac{A_1R_1}{A_2}$$

and

$$R_3=\left(\frac{A_1}{A_2-A_2}\right)R_1,$$

the value of the shunt to be fitted.

Manganin is the most suitable material for the shunt, and should be in strip form.

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Its advantages are :—

(1) High resistivity.
(2) Low temperature coefficient.
(3) Low thermo-electric force with copper.

The section of the shunt is determined by the current to be carried, the minimum section being about ·5 mm. square for 1 ampère. Thus a shunt for 20 ampères should be about 1 cm. × 5 mm. as it is important to have flat strip in order to get a large radiating surface.

The above section gives a drop of ·075V with about 4 cm. length. A larger section is better, but becomes more bulky. The section should not be less than this value however.

The strip may be corrugated if it is too long to fit the instrument case. It should be as open as possible. After final adjustment, which can be done with a fine file, it is necessary to shellac varnish the manganin as it oxidises rapidly in air.

(3) Moving Iron Instruments.

It is usually best to remove the existing wire from the bobbin and rewind. The strength of field in the coil depends on the ampère-turns, not on the watt consumption, and so only general considerations can be given. For a voltmeter to have a higher range its resistance must be increased. This may be secured by additional wire in series with or wound over on the bobbin, or by completely rewinding. It is necessary to note that the bobbin must be wound inductively, and the series resistance, if used, non-inductively. The wire may be either copper or constantan. Some instruments are wound with all the wire of constantan on the working bobbin, others have a copper winding on the bobbin and the series resistance, or another bobbin or card, of constantan. It is necessary that the ratio of constantan resistance to copper resistance should be not less than about 3 or 4, to keep the temperature coefficient down. The gauge of wire used should be similar to that already on, and usually rather thicker than that required for a moving coil instrument, as the current is greater.

Moving iron ammeters are not quite so simple to alter as voltmeters. The section of the wire or strip must be proportional to the current carried. In voltmeters the current is relatively small, about 100mA, and nearly constant for all ranges. The working current density must not exceed 4 ampères per square millimetre, for copper and for resistance wire 1 ampère per square mm. A high-range instrument will therefore have only two or three turns of thick strip, and a low range instrument a great number of turns of thinner wire.

Calibration must be done by trial, and if done on D.C., which is usually most convenient, it must be noted that the reading

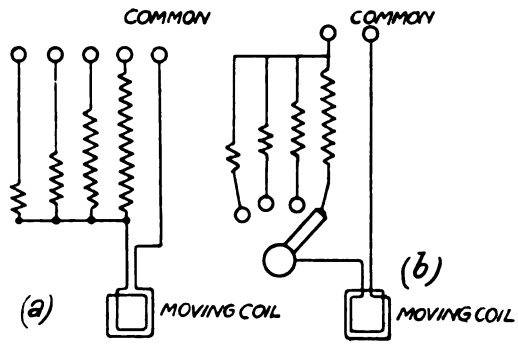

Fig. 3.

with increasing volts or current will be slightly lower than the corresponding value of decreasing volts. This is on account of the hysteresis of the iron. Reversal of the D.C. current at each reading will provide a useful indication of the mean value.

(4) Thermal Instruments.

This type is the least amenable to alteration. A new wire can be fitted, but is not advisable as it is a very delicate operation. The range may be increased, however, by shunting if an ammeter, and by series resistance for a voltmeter. This must be done by trial, as the resistance as measured on a Bridge, when cold, is about one-third or a quarter the resistance when hot under full load. A shunted instrument must be calibrated at its working frequency.

Multi-Range Moving Coil Instruments.

After finding the lowest possible range, as previously described, and from inspection of the scale, the ranges to be fitted may be settled. Any number is permissible; the only limit is in the accommodation for the resistances. The values of these for each range is calculated as before and the means of changing from one range to another is as follows :—

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Two methods are available. (*a*) A separate terminal for each range, and one "common" terminal. (*b*) One pair of terminals and a switch or plug and sockets. (See Fig. 3.)

Further, the separate resistances can be incorporated into one, as shown in Fig. 4, economising in wire, or they may be separate as in Fig. 3 (*a*) and (*b*). The latter method is easier to calibrate, as each range is independent of the others.

Either method may be used, and the construction is a matter for the individual, as instruments vary in size and shape.

Moving Coil Ammeters.

Four methods of range changing are available, and are shown in Fig. 5 (*a*), (*b*), (*c*) and (*d*).

(*a*) Is the simplest, as each range is independent of the others. It has the disadvantage, however, of requiring extra terminals and a switch or plug and sockets, both of which must be altered when it is desired to change the range when in use.

The method of proceeding with the first arrangement is as follows: Calculate the resistance of each shunt as given earlier. Fit each shunt to the common terminal and one other. From each range terminal fix a lead to a socket or to a switch stud. The plug or switch arm is then connected to the swamp or the coil, if the swamp is in the other lead. The common terminal is then connected through to the other coil lead. For these connections flexible or wire of about 20 S.W.G. will do, but it is important to make good soldered connections, and to have a well-fitting switch or plug and sockets.

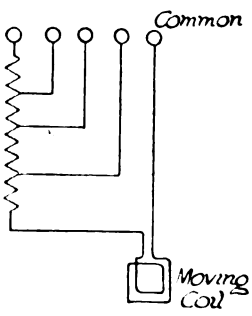

Fig. 4.

Arrangement (*b*) is simpler in use but more difficult to construct, especially when adjusting by trial. The largest shunt is across the common and the next terminal. When this range is in use the indicator is connected across the shunt through the smaller shunts in series. If, therefore, any of the shunts are subsequently adjusted the calibration of all ranges is upset. For this reason it is not recommended for conversion.

Arrangement (*c*) is very simple both to construct and to use, and is of use if the ranges are not widely different. For several ranges where the highest is many times the lowest it is not recommended. As there is only one shunt, this has to give the voltage drop required by the indicator when the smallest current range is in use. If the lowest range is, say, 1 ampère, and 50 millivolts drop are required the resistance must be ·05 ohm.

If, on the other hand, the highest range is 100 ampères the volt drop across the shunt is $100 \times \cdot 05 = 5$ volts, which is excessive, as well as requiring a much larger shunt. The purpose of the switch and series resistances is to limit the pressure applied to the indicator to that required for full scale deflection at each range. For two ranges of, say, 1 ampère and 2 ampères the procedure is as follows:—

Measure the potential required to produce full scale deflection by means of the millivoltmeter. This can be applied either across the indicator itself or across the complete shunted instrument, as it is the same value. Call this V_1. The resistance of the shunt must be such as to give the drop V_1 with 1 ampère passing.

This is $\frac{V_1}{1}$ ohms. Here no series resistance is used, the drop is applied directly to the indicator.

For the 2-ampère range there will be twice the volt drop across the shunt. The extra potential difference must be disposed of in the resistance, which must therefore be equal to the indicator resistance, so that the total resistance will be twice that of the 1-ampère circuit.

The construction may be with either a two-way switch or plug and two sockets. Good contact is essential. For the case of an instrument to which another range of double that of the present one it is possible to do the conversion without another instrument for calibration, but, if possible, another should be used as a check.

The procedure is this: Cut one lead from the shunt to the indicator. Attach the shunt lead to a socket or switch stud and connect the indicator lead to the plug or switch arm, whichever is used.

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If this is done well the resistance added will be negligible, and the instrument will still read correctly. For the other range wire up a resistance as shown in Fig. 5 (*c*), and whilst a current equal to full scale deflection is passing, change over the switch. Adjust the resistance until the deflection is half-scale only. When this is correct, the instrument will then require double the current for full scale on this range. If the shunt is of ample proportions this will be satisfactory, but if the shunt gets warm on the higher range it will not be accurate. A greater range than double should not be used with the existing shunt, but another one fitted of the same resistance, but larger cross-sectional area. It should be noted that if the section of a shunt is doubled, the length must also be doubled to give the same resistance.

Fig. 5 (*d*) shows the simplest means of adding a higher range to an ammeter. The existing wiring is left intact and a link is arranged to put an extra shunt in parallel with the other.

It can be extended to two or more ranges, but then some form of switch or plug and socket arrangement is preferable. A milliammeter of two ranges on the line of the above idea is described in detail later. The calculation of the shunt required is simple, but, as before, the difficulty of measuring it accurately on a Wheatstone Bridge makes it preferable to adjust by calibration. If the original range is A_1, and the resistance between terminals is R_1, the required terminal resistance for a range A_2 is

$$\frac{A_1 R_1}{A_2}$$

As part of this resistance is that existing, and is in parallel, the new shunt resistance must be

$$\left(\frac{A_1}{A_2 - A_1}\right) R_1$$

This includes the resistance of the link or switch and the leads, and so the resistance at the contacts should be low and constant or trouble will occur. If the shunt is determined by calibration, and not by calculation, no error is involved due to the resistances mentioned, provided they remain constant.

Moving Coil Volt-Ammeters.

The next possibility is that of converting and Fig. 3 (*b*), or Fig. 4, can be used as a single-range voltmeter or ammeter into a multi-range volt-ammeter. This can always be done, providing the inside of the instrument is accessible, but it is not always economical. The usual current for a voltmeter is about 15mA, and the potential drop across an ammeter about 75mV. If these values apply to an instrument under

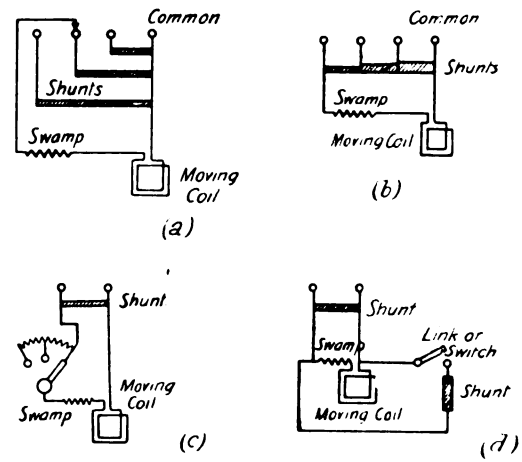

Fig. 5.

consideration a volt-ammeter is a practicability.

A voltmeter requiring only about 7mA instead of 15mA would naturally have a higher resistance. If this higher resistance necessitates a drop of more than about 100mV it is not economical to convert it to an ammeter. The writer has an instrument, which will be detailed later, which has a consumption of 7·3mA at full scale, and the indicator drop is 351mV. This is too much to use as ammeter, and so it is only used as a multi-range voltmeter. Another instrument, also described later, requires 50mV and about 18mA for full scale. This has been converted from its original purpose as a central-zero 5-ampère ammeter to a four-range volt-ammeter. The individual ranges of volts and ampères are calculated or fitted by trial exactly as before. The only addition is a switch for changing from volts to ampères. Fig. 6 shows the connections of the switch, (*a*) shows a single-range instrument, whilst (*b*) incorporates Fig. 6 (*a*) and Fig. 4 (*a*) to produce a multi-range instrument. The alternatives of Fig. 5 (*b*) and (*c*),

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stated before. Fig. 6 (*b*) is a three-range volt-ammeter, and is, of course, a much more useful instrument than the original single-range voltmeter or ammeter.

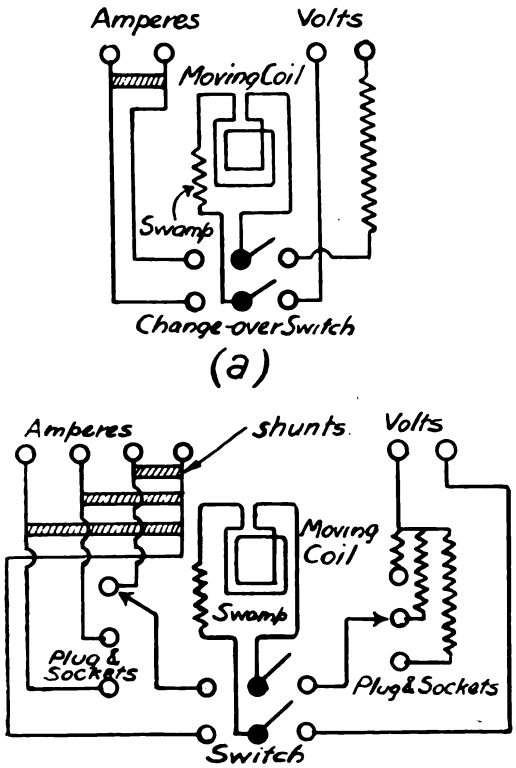

Fig. 6.

The number of ranges is unlimited, and left entirely to the reader.

Moving Iron Voltmeters.

The range of conversion for these instruments is not so wide as that of moving coil instruments, chiefly owing to the greater power consumption in the working coil. Several ranges, however, can be fitted, more especially if they are all higher than the original range. If the required lowest range is lower than the scale reading, some of the wire may be removed from the bobbin, if all the wire is on the working bobbin, or from the series resistance, if fitted. Removing the wire from the coil is not very good practice, for in order to produce full scale deflection, a certain number of ampère-turns are required. If, then, the turns are reduced in number, more current is required to excite the coil fully. The winding being designed for a given current, a higher rating than this will probably cause overheating, as well as greater power loss in the instrument. If higher ranges are required they can be calculated for and fitted exactly as for moving coil voltmeters, taking care to wind the resistances non-inductively in order to prevent their action on the working coil.

Moving Iron Ammeters.

These instruments are rarely shunted, and so, as the line current flows through the winding, the size of wire or strip used depends on the range. To increase the range of an ammeter, the best way is to re-wind, but if several ranges are required, it is usually simplest to arrange shunts, as shown, for the moving coil ammeter in Fig. 5 (*d*). If there is room on the working coil to wind more wire on, this may be done for a second range, using copper wire. The section of wire can be calculated from the range and the current density—4 ampères per square millimetre. Fig. 7 shows the connections. Three terminals only are required. Moving Iron volt-ammeters are not nearly so good as moving coil instruments, owing to the larger power consumption in the working coil. If a volt-ammeter is required, a moving coil instrument should be obtained.

Hot-Wire Instruments.

A second—higher—range may be fitted to a hot-wire ammeter if required. The shunt method with a link or plug as shown in Fig. 5 (*d*) is about the only method of

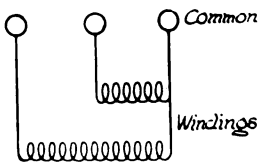

Fig. 7.

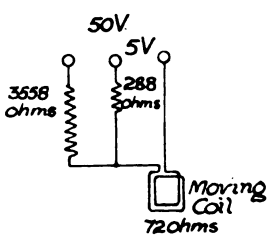

Fig. 8.

satisfactorily accomplishing this, and is quite satisfactory for one or two higher ranges.

The Limitations of Different Instruments.

As moving iron instruments can be purchased more cheaply than moving coil instruments, and as both will read on D.C., the

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usual circuit on which they are used, it is often the case that the moving iron instrument is bought. When accurate readings are required the cheap moving iron instrument is useless.

For indicating the approximate current they are of some use, but even then their high consumption often causes an appreciable waste of battery power. As an example, the anode battery circuit of a valve receiver will be considered. Assume that the voltage is nominally 50, and about 5 milliampères are required by the triodes. The ideal voltmeter for this purpose is an electrostatic instrument, but these are very expensive. A moving coil voltmeter can be used satisfactorily however. If the instrument requires about 15 milliampères for full deflection (and 50 volts) it is seen that the load on the battery is 5 + 15 milliampères, or only one quarter of the output is used on the set, and the rest wasted in the voltmeter.

Now, considering the moving iron voltmeter. This may require about 100 milliampères for full scale. The battery current is now 105 milliampères, which is not good for the battery, especially if not quite new. Also, the heavy current will reduce the potential difference at the battery terminals appreciably.

A moving iron instrument should not be employed on a low-power circuit therefore, and the above typical case should be thoroughly understood. It is possible that the prospective purchaser may not be able to recognise one from the other by inspection, and if ex-Army disposals instruments are under consideration, no real details of them are to hand. A moving coil instrument always has a uniform scale, and if wrongly connected in circuit, its pointer will tend to move the wrong way, *i.e.*, from right to left, except in the case of central zero instruments.

Moving iron instruments never have a truly linear scale. A number of them are proportional from the first 10 per cent. to the top of the scale, but the initial 10 per cent. is so cramped that it is usually omitted. If the instrument is known to be a moving iron one, and the scale is quite uniform, it should be left, as its scale is not true.

Hot-wire instruments are usually easy to distinguish. Their scales also are not uniform and usually commence cramped and continue to increase their divisions up to full scale. It will often be found that the pointer is not at zero. A screw is usually provided for adjusting this however. In use a hot-wire instrument is almost always "dead-beat," *i.e.*, it settles down to its reading without oscillations. Some are so much "damped" that they are sluggish in action. If the instrument is shaken, the pointer will not move, but with other instruments the pointer can be made to swing.

Converted Instruments.

A few cases of conversion of instruments performed by the writer will now be detailed.

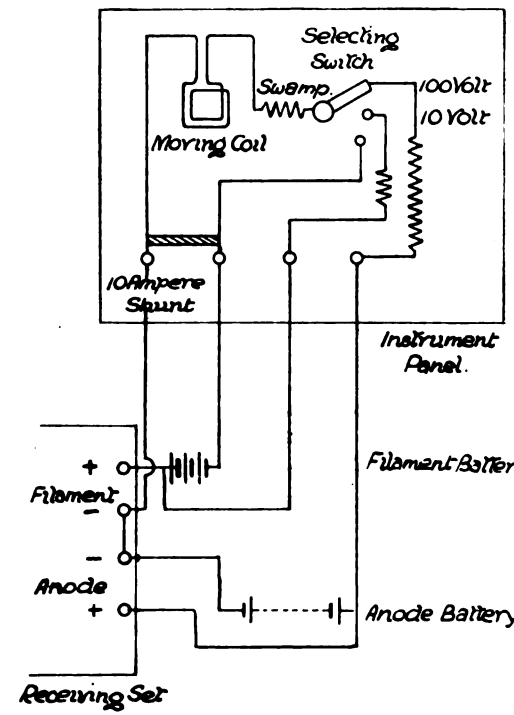

Fig. 9.

(1) N.C.S. 5-ampère moving coil ammeter, central zero, portable, in wood case, 5 in. by 4 in. This appeared to be a useful instrument for conversion, and the following ranges were fitted: 50mV, 1V, 2·5V, 10V, 25mA, 100mA, 1A, 5A. The low ranges were possible because the coil, when disconnected from its shunt, required 18mA at 50mV. The instrument was fitted complete in a larger wood case, with the original top and terminal block showing. Extra terminals were then fitted on each side of the others, a switch fitted in the centre of the top of the case, and two strips of four sockets with two plugs were affixed at

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the sides. The photograph (Fig. 10) shows the completed instrument at the left.

(2) Roller-Smith (American) voltmeter. 50 volts. A tapping was made between the coil and the series resistance, and on applying a potential to the coil only, the deflection was full scale for 1 volt. This precluded its use as an ammeter, for an ammeter with a drop of 1 volt is hopeless. However, the resistance of the coil was measured, and found to be 72 ohms. A range of 5 volts, *i.e.*, one-tenth, was decided to be fitted, so that the instrument would do for a 4-volt accumulator circuit. As the resistance of the coil is 72

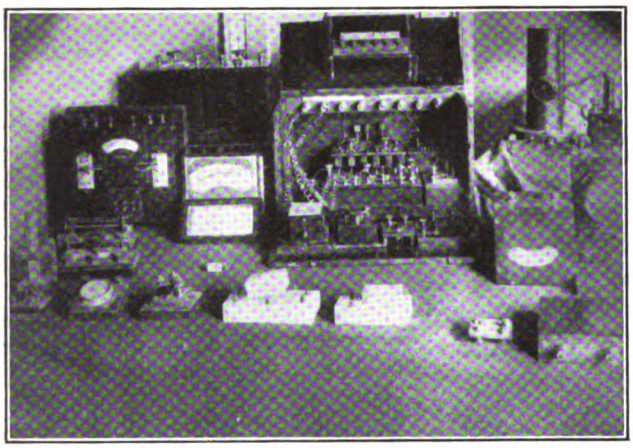

Fig. 10. *The completed instrument.*

ohms per volt, the added resistance had to dissipate 4 volts, and so had four times the coil resistance. This was done, and an external resistance of 288 ohms added. The connections are as shown in Fig. 8.

(3) Park Royal. 80 milliampères. The present range was of no use to the writer, and the shunt was removed. The current now was almost exactly 15 milliampères for full scale, and so a new scale was made and the instrument calibrated for 15mA. A shunt was added with a link, as in Fig. 6 (*d*), to give a range of 150mA, ten times the first. The resistance on the 15mA range is 4·45 ohms, and on the higher it had obviously to be one-tenth of this, or ·445 ohm. The shunt, therefore, was made of 0·5 ohm, and was adjusted by trial. Manganin wire was used, as the current is quite small.

(4) Elliot sub-standard voltmeter. 25 volts moving coil. Portable. This is the best of the writer's instruments, and many of them are now on sale from dealers. They are well worth the money. It was hoped to include extra resistance in the case, but on inspection it was decided not to, for this reason: To get a number of ranges a great number of resistances would have to be made up and fitted. The writer has several standard resistance boxes (seen in the testing set in the right centre of the photograph), and it was decided that a terminal could be fixed to the junction of the coil and resistance so that any resistance could be connected externally to give any volt range required. Accordingly, one terminal was fitted between the other two, and the lead connected to the coil. On trial, the voltage necessary to produce full scale was 351mV. This was too high for an ammeter, except a low-range milliammeter, but quite satisfactory for volt ranges. The coil resistance is 49·5 ohms, and the following ranges can be obtained by connecting through the resistance stated, externally :—

					Ohms.
·5 volt range.	Series resistance				19·2
1·0	,,	,,	,,	,,	87·8
2·5	,,	,,	,,	,,	294·0
5·0	,,	,,	,,	,,	636·5
12·5	,,	,,	,,	,,	1 666·5

And for 100 volts a resistance equal to that of the instrument (3 432 ohms) is put in series with the original terminals. Higher ranges could be obtained if desired.

It is also used as a milliammeter, but as the range is 7·3mA, it does not fit the scale. A shunt could be fitted to give a higher range, and fit the scale, but as the lowest possible range was required, no shunt was fitted, but it is used on its low-voltage range (*i.e.*, coil only, no added resistance), and the current calculated by slide-rule. It is not, therefore, direct reading as a milliammeter.

(5) Siemen's 10-ampère ammeter. Moving coil. Switchboard type. It was required to make this instrument serve the following purposes: Accumulator volts, anode battery volts, and filament current.

After several plans had been considered it was finally accomplished, and the instrument wired permanently in circuit with a three-way switch to change from one to the other circuit and range (Fig. 9).

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The Perfect Set.

Part V: The Last of L.F. Amplification. [R342·7

In this issue we complete, as far as we can in the space available, our treatment of L.F. work. We deal largely with tuned L.F. for telegraphy.

ALREADY two instalments of this series have been devoted to L.F. amplification, and still we have not completed a simple exposition of the bare beginnings of it. We have, however, dealt with (1) the valve, and (2) the coupling, on the basis of an attempt to amplify without distortion. Now we must devote a little space to amplifying *with* distortion, *i.e.*, tuned or part-tuned amplification for telegraphy.

We need not deal with it at length, partly because it is essentially an easier matter, partly because those interested in it have usually had rather more experience of wireless work than those who attempt the much more difficult task of broadcast reception—that is one of the topsy-turvy tricks of life!

For telegraphic work we can concentrate on the reception of one note. Not only is it easier to do so, but it is actually advantageous, for it helps to eliminate the unwanted notes of other stations. The first matter is to choose the note. It was probably accidental in the beginning that the usual telephone is most sensitive to a note round about 800-1 000 cycles, which is also the pitch to which the average ear is most sensitive. Modern telephones made for wireless telegraphy have this resonance accentuated as far as possible. Since, luckily, the use of C.W. for transmission enables us to choose our own note for reception, we shall obviously design our amplifier for a frequency within this range, and adjust the beat note to suit.

How then shall we design the receiver? Since we want maximum amplification we shall obviously use transformers, and we shall try to tune these transformers. We say *try*, for it is not so easy to tune an L.F. transformer as an H.F. Sharpness of resonance (at any given frequency) depends on the ratio of inductance to resistance, and it is difficult to make this ratio large for an instrument like an inter-valve transformer. If sharpening is required special steps must be taken—luckily they are easy ones.

First, however, as to tuning. Each transformer can be tuned by a condenser across primary or secondary. It is unnecessary to tune both for *as far as tuning goes the two circuits behave as one.* This is quite an important point, and applies also to H.F. transformers if they are close-coupled: the proper condenser across *either* winding will tune the whole; and the proper condenser across the small winding is S^2 times that across the large one, if S is the turns ratio. In actual practice many transformers naturally tune not far from 1 000 cycles: if they do not, a condenser of less than $\cdot 001\mu F$ across the secondary is usually sufficient. High ratios should be chosen (1 to 5 or 1 to 6, or even more), as they can easily be made to give their full step-up at one frequency by tuning.

Another point is, that of the total alternating voltage in the anode circuit of a valve, only part is applied to the transformer, part being absorbed in the valve. At its resonant frequency the transformer will probably have an apparent input impedance of 500 000 ohms or more (see the recent series by D. W. Dye, in E.W. & W.E. for September, October and November, 1924) compared with 20 000 ohms for the valve, so that there is not much in this: however, there will be an improvement by using valves of low impedance compared with their amplification—power valves, in fact. It seems foolish to suggest power valves for bringing faint distant signals to telephone strength, but sometimes there is a great gain by doing so. It depends largely, however, on the next point to be brought forward.

This is reaction. It does not seem to be generally realised that reaction is quite easily applied to audio-frequency amplifiers, resulting in a great increase of amplification combined with sharp note-tuning. It is, of course, difficult to use inductive reaction, although it can be done by a back-coupling transformer with a movable iron core. But it is by no means difficult to arrange capacity reaction. All that is necessary is to couple the grid of the last valve, through

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a condenser, to the grid of the first. The "tightness" of the coupling depends on the size of the condenser, and it is almost impossible to give this value, for it depends on the μ of the valves, the step-up of the transformers, and on all the transformer losses. In some cases a variable condenser of ·001 gives ample reaction, causing the set to howl if used all in. In other cases one must use something much larger.

Lastly, do not forget that though distortion is not important in this work, grid bias is as necessary as ever in order to get amplification.

Designing an Amplifier.

Perhaps we can now try and give some actual suggestions as to the design of an amplifier; and we shall confine these suggestions to broadcast work, for (as we have already said) those doing long-distance work in most cases know all about it.

Our amplifier will have its input connected either to a valve or a crystal, and the first transformer must be designed accordingly. A valve when used as detector is likely to be used at a low filament heat, and its impedance will probably be high. Therefore, the input transformer should be of low ratio—say, about 3 to 1. If we are using a special high μ detector valve, without grid condenser, an even lower ratio may be best.

But if we are using a crystal—especially a galena crystal—we may have a much lower input impedance, which means a higher ratio: 6 to 1 or 8 to 1 is called for here. In either case the primary will probably want a by-pass condenser. A value of ·0001 is really sufficient, and should not be greatly exceeded for the valve detector. But for the crystal-to-valve transformer with its high ratio there is no objection to using a larger one, up to ·001, although a condenser of this size may quite probably by-pass some of the audio-frequency energy.

Now as to the valves. For domestic work it can be given as our definite opinion (although we are shy of "definite opinions") that not more than two stages should be used. If they do not give sufficient volume the input to the detector must be small, and this leads to distortion. The remedy is H.F. amplification. If good tone is required, see that the rectifier is supplied with plenty of power, and then more than two stages will be unnecessary for work in even a large room.

Of course, if resistance or choke coupling is used with valves of low magnification, three stages might be necessary. But now that special high μ valves are made for such work we need not consider such an inefficient combination.

For loud-speaker work, the last valve must be chosen, before everything, for sufficiency of power output. Bearing in mind the points made in the discussion on valves (E.W. & W.E., December, 1924, p. 153), we can take it that 15 volts swing must be catered for. It is obvious that, with a constant input, the higher the magnification the bigger the output. With a μ of 8 it is probable that the valve must be capable of giving 40mA or so of maximum saturation current in order to get full power without distortion. With a μ of 5, a valve capable of about 25mA would do. There is little difficulty in picking a suitable type from among those we have described from time to time: it is probable that we can make our final choice so that the filament voltage required suits the battery used for other valves.

As to the first valve, we have a free hand. The input to it will probably not exceed 1 volt, and it will be found that practically any "general purpose" valve, with the usual saturation output of 6mA or more, will be sufficiently powerful.

It will usually be found that valves specially sold for L.F. work have a low μ and correspondingly low anode impedance ($\mu=5$, $R_a=15\,000$ are common values), while both these values are higher for "H.F." valves, which may give $\mu=10$, $R_a=25\,000$. As we have already explained, these changes often compensate each other, and either valve may give the better results *if it has a good "straight" characteristic.* On our own set, picking transformers to suit the valve to be used, we usually find "H.F." valves considerably better than L.F.! The L.F. valves, however, usually need less H.T. voltage with a given grid bias. But a power valve for the first stage, though unnecessary, may often give higher amplification owing to its high ratio of μ to R_a.

An important point in connection with the valves is to put the filament resistances on the positive side. The idea of using the odd volt lost across the filament resistance

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is a snare: every change of filament volts upsets the grid bias. No, put the rheostats on the + side, and provide bias batteries. It may not be necessary to provide filament rheostats at all, but we prefer it, for one often likes to use valves of rather higher rating than strictly necessary, in order to under-run them and thus secure long life. But remember that some dull-emitters do not like to be much under-run, and may even cease to "dull-emit" if this is done consistently.

Next, as to the provision of separate grid and anode supplies for the two amplifying valves. If the first valve is a dull-emitter it is not wise to apply much more than 100 volts to it, even if the output is kept down by biasing. The reasons seem to the writer so interesting that a digression will be made to give them.

A Digression.

If a valve is not *absolutely* hard, there will be positively-charged ions of gas in it. These will move in the opposite direction to the normal electron stream, and thus will strike the filament. This "ionic bombardment" in time disintegrates the filament. In the case of the thin filaments of dull-emitter valves there is no surplus of filament, and the life would be short under bombardment. Further, such bombardment dislodges the thorium coating of a dull filament, and, if excessive, will clear the filament of thorium more quickly than fresh supplies can be diffused from within the filament body, and so spoil the emission. Hence a very hard vacuum is an essential. But even if the valve is very hard, if electrons strike the glass of the bulb hard enough they will dislodge ions. Now the electrons are set in motion by the H.T. field, and those that pass the anode have a speed depending on the H.T. voltage. As they go on, they are moving away from the anode against the H.T. voltage; hence they are slowing up. The larger the bulb the slower they will be travelling when they hit the glass. Hence the chance of their striking out ions which damage the filament depends on the H.T. voltage and the size of the bulb. With the usual size of ".06" valves, voltages over 100 volts may shorten the life.

Returning to our main point—the question of grid and anode tappings—we shall probably need about 8 volts bias on the last valve, which with most valves will necessitate more than 100 volts of H.T. If then we are using a ·06 valve for the first, that means two anode voltages, and with most types of ·06 valve this in turn will need two grid bias values. But if we are willing to be at some pains to choose suitable valves, or if we care to sacrifice a little economy in filament current by using a power-valve for the first, we can almost certainly use *either* one grid bias or one anode voltage, and quite possibly only one value of each. Just as an indication of suitable values where separate supplies are used, the writer will quote those on his set at the moment:—

	1st Valve.	2nd Valve.
Type	Mullard D ·06 H.F.	M-O.D.E. 5
Filament Rating ..	2·5-3V, ·06A	5·5V, 2·5A
Actual Voltage on Filament	2·7	4·9
Actual Voltage on Grid	—3·0	—9·0
Actual Voltage on Anode	90	135
H.T. Current (mA) ..	1	4·5

Note the last item: this is read on a milliammeter permanently in the common return: the individual currents are read by lifting one H.T. plug for a moment

Remember that a change of phone or loud-speaker resistance changes the actual anode volts. You can check this by reading the current.

Although there is much more to be said on the subject, we must leave L.F. work for a while. In our next instalment we will get on with H.F. amplification.

Ship's Orchestra Broadcast.

A "SHIP'S orchestra repeater" which will enable music played in the saloon to be heard throughout the ship has been installed by the Marconi Co. on the liner *Montclare* of the C.P.O.S. By means of the Marconiphone which has lately played a prominent part in large public gatherings and carried the voice of the Prince of Wales to thousands at the closing ceremony of the Wembley exhibition, orchestral music can be repeated in any part of the ship, including the crew's quarters. Dance music will be provided on various decks and also lectures and concerts.

The *Montclare* is the first ship to be equipped with this apparatus, and it is interesting to reflect that, but for the progress in wireless directly due to broadcasting, the loud-speaking telephone would have continued in the stage of arrested development in which it remained for so many years, and the possibilities of a public address system would never have been realised.

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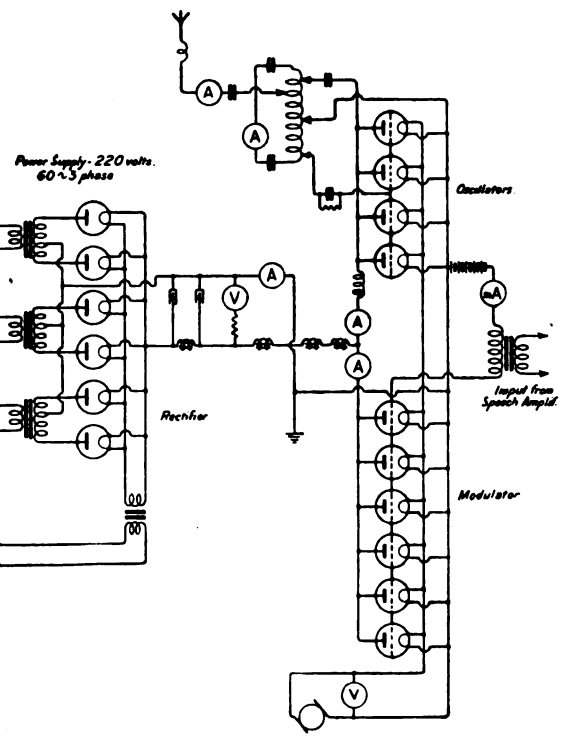
KDKA Short-Wave Station.

[R612

Some notes on the Westinghouse Company's station at Pittsburg.

THE new site of the short-wave station of KDKA is in direct contrast to its former location. When first installed, the short-wave transmitter was situated on the top of a nine-storey building in the heart of the Westinghouse Company's East Pittsburg Works and was then surrounded by steel buildings in addition to being in a valley almost surrounded by hills. The main transmission station of KDKA is still in the same position, and in spite of the many apparent drawbacks has accomplished many famous transmissions that will remain on record in the history of wireless.

The new building, a one-storey concrete and brick structure, has been erected on the Greensburgh Pike and is within a few feet of being the highest spot in Allegheny County. Particular attention has been given in the planning of the station to so arranging the apparatus that the whole installation shall be at once symmetrical and easy of inspection.



A schematic diagram of the transmitting apparatus used at KDKA.

The basement is divided into several rooms. The main basement chamber contains the high-power transformer plant, motor generator sets, filters, chokes and other apparatus. The remainder of the basement is occupied by the battery room, furnace room, and storage space. Power is brought into the basement through underground conduits from two separate sources, both of which are 4 000-volt, three-phase, 60 cycles. This current supply may be stepped up or down as required. The available power supply is approximately 250 kilowatts, which can, however, be increased should it be necessary.

The main apparatus room on the first floor of the building, which contains the oscillator, modulator and rectifier panels, is of ample area, and having windows on all four sides is well-lit by day.

The rectifier which furnishes high voltage to the anodes of the water-cooled valves is mounted on a specially designed frame, so that every part of the apparatus is accessible. Replacements and observations can be made conveniently, as every part of the unit is in full view of the supervisor. The rectifier has a capacity which can be pushed to 150 kilowatts, if necessary, and is the outcome of several years of experimental work by the Westinghouse Company in short-wave broadcasting.

The oscillator panel is of the same general construction as the rectifier panel; and Westinghouse high-power, water-cooled, copper-anode transmitting valves are mounted on it. They are not ordinarily subjected to maximum capacity, but are usually paralleled. Thus each valve is subjected to about half its rated capacity and an unusually long life in valves results. As in the case oi the rectifier, every part of the oscillator panel can be observed and replacements made without difficulty. The modulator panel, using the same general type of valves, has a switching arrangement

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whereby the number of valves and the amount of power used can be regulated.

Adjoining the main room and extending a few feet into it is the control room. The front and extended sides of the room have glass windows so that every part of the apparatus room may be constantly seen by the operator. This room is equipped with amplifying apparatus consisting of two units, one using 5-watt valves, the other using 50-watt valves. The start and stop control switches, line terminals, amplifying connections, etc., are all located in this room. The engineer at his desk, therefore, can control everything in the station and can also listen and hear the signals, thus judging them for quality.

The aerial is a copper tube erected vertically, supported rigidly from a pole about 50 feet high. Extremely fine results have been obtained from this perpendicular type of antenna, and although only one is now installed, several others will be erected at various points about the station in order that directional experiments may be made.

The Exhibition of the Physical Society.

A Fine Display of Wireless Apparatus. [R064

THE Annual Exhibition of the Physical Society of London always makes a strong appeal to the student of physics, and the fifteenth exhibition, which was held on January 7 and 8 at the Imperial College of Science, was well up to the high standard that the visitor is now accustomed to expect.

It was interesting to note the increase in the number of well-known instrument manufacturers who are now devoting great attention to wireless, and both research and construction were adequately represented. It is impossible in a brief account to do full justice to all the firms exhibiting, but if any are omitted it is not for lack of merit, but of space.

An improved design of the Duddell Oscillograph was shown by the Cambridge Instrument Co. The outstanding feature of this instrument is that simultaneous records may be obtained from three vibrators, which may be any combination of the electromagnetic and electrostatic types, only one camera and one source of light being required.

Both fixed and variable air condensers, constructed in accordance with the Lawes modification of the Kelvin system, were also shown.

The Zamboni H.T. disc batteries which have been developed by Major Phillips were another interesting exhibit. These consist of a number of paper discs coated on either side with metal foil, each disc giving approximately 0·5 volts. The standard battery gives a voltage of 500 and is easily portable.

A fine display of bright and dull emitter valves exhibited by Messrs. Cossor included a large model illustrating the special features of the valve, and a large selection of valves was shown by the M.O. and Mullard Valve Companies. The latter also showed the Holweck molecular pump.

Condensers of every description, ranging from the laboratory standard down to small types familiar in wireless sets, were naturally the chief feature of Messrs. Dubilier's stand, but they also had many other instruments including a short-wave heterodyne wavemeter

Two very interesting wireless instruments were exhibited by Messrs. Evershed & Vignoles. The first was the Evershed 1000-volt generator for the supply of H.T. current in transmitting circuits. This has been designed for use in amateur stations, and has proved highly successful in a number of special tests, including transatlantic transmission of morse and the transmission of speech from a motor vehicle while travelling at high speed. The other wireless exhibit was the Frost emergency wireless signal apparatus, a remarkably compact transmitter that can be operated by an unskilled person. As it measures only 11 by 12 by 9 inches it occupies but little space in a lifeboat, and a point in its favour is that it can be placed quickly in the boat most likely to be lowered first. Turning a handle sends out the S.O.S. signal automatically by means of the Frost transmitting drum on either I.C.W. or C.W., but the I.C.W. set is considered the best for marine work. There is only one switch on the set, and this provides a means of lighting a mast-head lamp so that the boats may keep in touch, the power for both wireless

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and lighting being provided by the hand operated Evershed generator. The C.W. set is only a trifle larger and is well suited to aeroplane work. Both types have a range of 60 miles in emergency conditions.

The stand of Messrs. Gambrell Bros. exhibited a complete range of instruments for all classes of laboratory and commercial work. Bridges of the Wheatstone and Kelvin type occupied a prominent place in the display.

A novelty in the form of variometers figured in the comprehensive exhibit of the Igranic Co., which covered a very wide field. This consisted of their B and BL types which have not been exhibited hitherto and are of interest both electrically and mechanically, as the windings of both rotor and stator are self-supporting, the use of moulded material being eliminated, thus justifying the claim that they are "wound on air."

The Silvertown Co., in addition to an interesting show of testing sets and measuring instruments, had a good assembly of L.F. transformers, headphones, condensers and loud-speakers and also many examples of the telegraph instruments that are now used in high speed wireless telegraphy.

Both the Marconi Co. and Marconiphone Co. had interesting stands, the former exhibiting a new and convenient public speech microphone with amplifier and loud-speaker, while among the instruments shown by the latter was a series-parallel variometer. By means of a simple switch this component may be used on a band of wave-lengths from 300 to 1 800 metres.

A standard multivibrator wavemeter was demonstrated by Messrs. H. W. Sullivan. This instrument is due to Mr. Dye of the N.P.L., and depends for its action upon the control of the fundamental frequency of an Abraham-Bloch Multivibrator, auxiliary apparatus for the selection and selective amplification of the desired harmonics from the multivibrator being provided. A group of instruments specially designed for the precision measurement of alternating currents of frequencies up to several thousand cycles per second was also shown.

The Interior of the Control Room at KDKA (*see p.* 304.)

The many fine examples of the instrument maker's art shown by Messrs. H. Tinsley and Co. included a wave meter designed by Mr. Dye of the N.P.L., having a range of from 600 to 5 000 metres. The variable air condenser of the meter is similar to their standard air condenser and amber is used throughout for insulation.

The laboratory and commercial instruments of the Weston Company are too well known to need description, but an attractive new item was provided in their miniature precision D.C. instruments. The moving system of these beautiful little instruments weighs only 5 grains and the quality of workmanship is equal to that of their standard instruments.

Altogether a most interesting and valuable exhibition, and an excellent exposition of British workmanship.

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A Short Esperanto-English Dictionary of Radio Terms. [399(R800)

This dictionary has been specially compiled for E.W. & W.E., and is companion to that which appeared in the January issue. For a few of the terms synonymous expressions have been given pending international standardisation.

Abbreviations.

- separates the *root* word from its ending; it also represents the repetition of the *root*.
— represents the repetition of the whole word in Esperanto.
n. .. noun.
adj. .. adjective.

A

Aer-o, air; **-a,** of air, air (*adj.*); **-a dielektriko,** air dielectric; **-a kondensatoro,** a. condenser; **-a kerno,** a core; **-kerna transformatoro,** a. core transformer.
agord-i, to tune; **for-i, mal-i,** to detune, tune out; **re-i,** to retune; **-a,** tuning (*adj.*); **-a bobeno,** t. coil; **-a kondensatoro,** t. condenser; **-o,** tuning (*n.*); **akuta -o,** sharp t.; **delikata (subtila) -o,** fine t.; **kruda -o,** coarse t.; **neakuta -o,** flat t.; **-ilo,** tuner; **multopa -ilo,** multiple t.; **-ita,** tuned; **akute -ita,** sharply t.; **ne-ita,** untuned.
akumulator-o, accumulator, storage battery (*see* **Sintoniz-i.**)
akut-a, sharp, acute; **—agordo,** s. tuning; **ne-a agordo,** flat tuning.
alĝustig-i, to adjust; **-ebla,** adjustable.
alt-a, high; **—frekvenco,** high (radio) frequency (H.F.); **—tensio,** high tension (H.T.); **mal-a,** low.
altern-a, alternating; **-a kurento,** a. current (A.C.); **-ilo,** alternator (*see* **Alternatoro**).
alternator-o, alternator; **altfrekvenca—,** high frequency a.; **dufaza** — two-phase a.; — **kun turna fero,** induction a.; **motoralternatora grupo kun diska sparkilo,** motor a. disc set; **multfaza—** multiphase (polyphase) a.; **turbo-** — turbine a.
alumini-o, aluminium.
amator-o, amateur; **radio- (senfadena)—,** radio (wireless) a.
amortiz-o, damping; **antena—,** damping of antenna; **granda—,** high d.; **-aj ondoj,** damped waves.
amper-o, ampere; **-turnoj,** ampere turns; **mili-o,** milliampere; **-metro,** ammeter; **alternkurenta-metro,** A.C. a.; **kontinukurenta-metro,** D.C. a.; **movbobena-metro,** moving coil a.; **varmfadena-metro,** hot-wire a.
amplif-i, to amplify; **-a,** amplifying; **-a valvo,** a. valve; **-o, -ado,** amplification (*action of amplifying*); **-eco,** amplification (*state*); **altfrekvenca -ado,** H.F. a.; **duala -ado,** dual a.; **malaltfrekvenca -ado,** L.F. a.; **-ilo,** amplifier (*see* **Amplifikatoro**).
amplifikator-o, amplifier; **altfrekvenca—,** H.F. a.; **malaltfrekvenca—,** L.F. a.; **magneta—,** magnetic a.; **rezistanca—,** resistance a.; **transformatora—,** transformer a.
amplitud-o, amplitude.
anod-o, anode, plate; **agordita—,** tuned a.
anten-o, aerial, antenna; **artefarita—,** artificial a.; **direktebla—,** directional (*moveable*) a.; **direktita—,** directional (*fixed*) a.; **funela—,** funnel-shaped a.; **horizonta—,** horizontal a.; **kadra— (kadro),** frame, loop, a.; **kaĝa—,** cage a.; **kolbasa—,** sausage a.; **L-forma—,** L-shaped a.; **nefermita—,** open a.; **ombrela—,** umbrella a.; **pendanta—,** trailing a.; **radianta—,** radiating a.; **riceva—,** receiving a.; **senda—,** transmitting a.; **T-forma—,** T-shaped a.; **vertikala—,** vertical a.; **-a amortizo,** damping of antenna; **-a portilo,** antenna support.
aperiod-a, aperiodic.
aparat-o, apparatus.
apuda kupleco, close (tight) coupling.
aranĝ-o, device, arrangement.
ark-o, arc.
asinkron-a, asynchronous; **—sparkilo,** a. discharger.
atmosfer-o, atmosphere; **-aĵoj (atmosferaj perturboj),** atmospherics, strays, static, X-s.
aŭd-i, to hear; **-ebla,** audible; **-ebleco,** audibility; **dis-igi,** to broadcast (*see* **Brodkasti**).
aŭdion-o, audion.
aŭtodin-o, autodyne, endodyne, self-heterodyne.
aŭtomat-a, automatic.

B

Bakelit-o, bakelite.
bateri-o, battery; **alt-tensia—,** H.T. b.; **anoda—,** anode b.; **filamenta—,** filament b.; **malalt-tensia—,** L.T. b.
bat-oj, beats.
bobeno-o, coil; **aerkerna reaktanca—,** air core protecting choke coil; **aldona (longiga)—,** loading c.; **anoda—,** anode c.; **araneaĵa—,** spiderweb c.; **cilindra—,** cylindrical c.; **ĉelara—,** honeycomb c.; **enŝtopa—,** plug-in c.; **indukta—,** choking c.; **induktanca—,** inductance c; **korba—,** basket c.; **kupla—,** coupling c.; **mezura—,** measuring c.; **solenoida—,** solenoid c.; **Tesla—,** Tesla c.; **reaktanca—, ŝok—,** choke c.; **-ujo, -tenilo,** c.-holder, -stand; **fiks-o,** stator (*see* **Statoro**); **turn-o,** rotor (*see* **Rotoro**).
born-o, terminal.
braz-i, to solder (*see* **Soldi**).
brodkast-i, to broadcast; **-a,** broadcasting (*adj.*); **-a stacio,** b. station; **-o, -ado,** broadcasting (*n.*).

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C

Ĉiferplat-o, dial.
cikl-o, cycle.
cirkuit-o, circuit, hook-up; **fermita—,** closed c.; **krada—,** grid c.; **intera (pera)—,** intermediate c.; **mallonga—,** short c.; **nefermita—,** open c.; **oscila—,** oscillating c.; **radianta—,** radiating c.; **refleksa—,** reflex c.; **rejeta—,** rejector c.; **rekta—,** straight c.; **-a,** circuit (*adj.*); **-a interuptoro,** c. breaker.
ĉapo, cap (*of telephone earpiece*).

D

Dekoheror-o, decoherer.
dekrement-o, decrement.
dekremetro, decremeter.
detekt-i, to detect; **-ilo,** detector (*see* **Detektoro**).
detektor-o, detector; **kompensita kristala—,** balanced crystal d.; **kristala—,** crystal d.; **magneta—,** magnetic d.; **perikona—,** perikon d.; **valva—,** valve d.; **termo-—,** thermo-d.; **termo-elektra—,** thermo-electric d.
dielektrik-o, dielectric; **-a,** dielectric (*adj.*); **-a konstanto,** d. constant, specific inductive capacity; **-a firmeco,** d. strength; **-a streĉo,** d. stress.
dinam-o, dynamo, continuous current generator; **kompunda—,** compound d.; **mem-ekscita—,** self-excited d.; **ŝunta (deriva)—,** shunt d.; **—kun sendependa ekscito,** separately excited d.
diod-o, diode, two-electrode valve.
dipleks-a, diplex.
direkt-o, direction; **-o-trovilo,** d.-finder; **-ebla anteno,** directional (*moveable*) aerial; **-ita anteno,** directional (*fixed*) aerial.
disk-o, disc.
distord-i, to distort; **-o,** distortion.
drat-o, wire (*see* **Fadeno**).
dual-a, dual; **—amplifado,** d. amplification.
dupleks-a, duplex.

E

Ebonit-o, ebonite.
efektiv-a, effective.
efik-a (valoro), root mean square (value).
efik-eco, efficiency
ekscit-i, to excite; **-ilo,** exciter (*see* **Ekscitatoro**); **mem-a,** self-excited
ekscitatoro, exciter.
eksperiment-o, experiment; **-i,** to experiment; **-isto,** experimenter.
ekvilibritaj signaloj, balancing signals.
elektr-o, electricity; **—mova forto,** electromotive force; **termo-a,** thermo-electric; **—magneta,** electro-magnetic; **—statika,** electro-static.
elektrod-o, electrode.
elektroliz-a, electrolytic.
elektron-o, electron; **-a elsendo,** electronic emission
elimin-i, to eliminate; **subondeta -o,** ripple elimination.
elmet-o, output.
elsend-o, emission (*see* **Emisio**).
emisi-i, to emit; **-o,** emission.
energi-o, energy.
enira (fadeno), lead-in (wire).
enmet-o, input.
esting-i, to quench, extinguisb; **-ita,** quenched; **-ita sparko,** q. spark; **-a sparkilo,** q. spark gap.
eter-o, ether, æther.

F

Faden-o, wire; **dividita—,** stranded w.; **enira—,** lead-in w.; **fleksebla—,** flexible w.; **izolita—,** insulated w.; **nuda—,** bare w.; **solida—,** solid w.; **-i,** to wire; **-ado,** wiring (*action*); **-aro,** wiring (*collection of wires*); **-aranĝo,** wiring (*method of wiring*); **sen-a,** wireless.
fajl-i, to file; **-aĵo,** filings.
faktor-o, factor; **—de potenco,** power f.
farad-o, farad; **mikro-o,** microfarad.
faz-o, phase; **mult-a,** multiphase, polyphase.
ferm-i, to close; **-ita,** closed; **-ita cirkuito,** c. circuit.
fibr-o, fibre.
fiksboben-o, stator (*see* **Statoro**).
filament-o, filament; **hela—,** bright f.; **malhela—,** dull f.
filtr-i, to filter; **-ilo,** filter.
fleks-ebla, flexible.
flu-o, flow (*see* **Kurento**).
formul-o, formula; **—de Thomson,** Thomson's f.
frap-ilo, tapper.
frekvenc-o, frequency; **alta—,** high (radio) f.; **malalta—,** low f.; **onda—,** wave f.; **ondara—,** group f.
fulm-o, lightning; **-ŝirmilo,** l. arrester.
fundament-a, fundamental, natural.
funkci-i, to function, work; **-igi,** to operate, cause to function.

G

Galen-o, galena.
galvanometr-o, galvanometer.
gener-i, to generate; **-o, -ado,** generation; **-ilo,** generator (*see* **Generatoro**); **re-i,** to regenerate; **re-o,** regeneration, reaction.
generator-o, generator; **—de kontinua kurento,** continuous current g.
glat-a, smooth; **-igi,** to smooth.
glim-o, mica.
grad-o, degree, co-efficient (*see* **Koeficiento**); **kupla—,** coupling c.
grajna koheroro, granular coherer.
grajna mikrofono, granular microphone.

Ĝ

Ĝiger-o, Jigger, oscillation transformer.

H

Harmonik-o harmonic.
hel-a, bright; **—valvo,** bright (emitter) valve; **mal-a,** dull (emitter) valve.
heliks-o, helix.
henri-o, henry; **mikro-o,** microhenry.
Hertza ondo, Hertzian wave, electromagnetic wave.
heterodin-o, heterodyne; **mem-o,** self-h.; **super-o,** super-h.
hidrarg-o, mercury.

I

Impedanc-o, impedance.
indukt-o, induction; **mem-o,** self-induction; **-a,** inductive; **-a motoro,** induction motor; **ne-a, sen-a, ŝunto,** non-inductive shunt.
induktanc-o, inductance; **antena—,** aerial i.; **antenagorda—,** aerial tuning i. (A.T.I.); **primaria—,** primary i.; **sekundaria—,** secondary i.
inert-a, inert; **-eco,** inertia.

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inkandeska katodo, incandescent cathode.
inter, amongst, between; **-a,** intermediate; **-a cirkuito,** i. circuit; **-valva,** intervalve.
interfer-o, interference (*see* **Ĵami**).
interupt-i, to cut out, switch off; **-ilo,** interrupter (*see* **Interuptoro**).
interuptor-o, interrupter, cut out switch, make-and-break; **aŭtomata—,** automatic cut-out; **cirkuita—,** circuit breaker; **elektroliza—,** electrolytic interrupter; **hidrarga—,** mercury i.; **hidrarga turbo-o,** mercury turbine i.; **martela—,** hammer break, trembler; **ŝarĝa—,** charging switch; **—de indukta bobeno,** induction i.; **—de kampo,** field break switch; **—de kurento,** current i.; **-a tabulo,** switchboard (*see* **Ŝalto, Komutatoro**).
izol-i, to insulate; **-ita,** insulated; **-eco,** insulation (*state*); **-ilo,** insulator (*see* **Izolatoro**).
izolator-o, insulator; **fleksebla—,** flexible i.; **—de eniro,** leading-in i.

Ĵ

Ĵako, jack.
ĵam-i, to jam; **-o, -ado,** jamming.
ĵul-o, joule.

K

Kadr-o, -a anteno, frame aerial, loop antenna.
kalibr-i, to calibrate; **-o, -ado,** calibration.
kamp-o, field; **elektra—,** electric f.; **magneta—,** magnetic f.; **interuptoro de—,** f. break switch; **reostato de—,** regulating resistance.
kapacit-o, capacity; **antena—,** aerial c.; **mem-—,** self-c.; **rezistanca—,** resistance c.; **superfluaj -oj,** stray capacities.
kapacitanc-o, capacitance.
karbon-o, carbon; **-diska mikrofono,** c. disc microphone; **-cilindra mikrofono,** c. rod microphone.
karborund-o, carborundum.
kaskad-o, cascade; **-a formo,** c. formation; **-e,** in cascade.
"katlipharo," "cat-whisker."
katod-o, cathode; **inkandeska—,** incandescent c.
kern-o, core; **aera—,** air-c.; **fera—,** iron-c.
klav-o, key; **senda—,** sending k. (*see* **Manipulatoro**).
klem-o, terminal (*see* **Borno**).
kod-o, code; **Morsa—,** Morse c.
koeficient-o, coefficient; **kupla—,** coupling c.
koher-i, to cohere; **mal-i,** to decohere; **-ilo,** coherer (*see* **Koheroro**); **mal-ilo,** decoherer (*see* **Dekoheroro**).
koheror-o, coherer; **fajlaĵa—,** filings c.; **grajna—,** granular c.
kompens-i, to compensate, to balance; **-ita,** balanced; **-ita ricevilo,** b. receiver; **-itaj signaloj,** balancing signals; **-ita kristala detektoro,** balanced crystal detector; **-ilo,** compensator (*see* **Kompensatoro**).
kompensator-o, compensator.
kompon-i, to compose; **-aĵo,** component, part.
kompund-a, compound.
komun-a, mutual, common; **—konduktanco,** m. conductance.
komut-i, to change over, to switch over; **-o,** changing over, switching over; **-o por ricevo,** change of connections for receiving; **-o por sendo,** change of connections for transmitting, **ilo,** change-over switch (*see* **Komutatoro**).
komutator-o, change-over switch, commutator; **dupolusa—,** double-pole switch; **duvoja—,** two-way s.; **turna—,** rotary s.; **—a tabulo,** s.-board.
kondens-i, to condense; **-ilo,** condenser (*see* **Kondensatoro**).
kondensator-o, condenser; **alĝustigebla—,** adjustable c.; **antenagorda—,** A.T.C.; **bloka—,** blocking c.; **fermita cirkuita—,** C.C.C.; **sekundaria cirkuita—,** secondary circuit c.; **duopa—,** twin-coupled c.; **varia (variigebla)—,** variable c.; **verniera—,** vernier c.; **—kun malgranda perdo,** low-loss c.
konduk-i, to conduct; **-ilo,** conductor, lead (*see* **Konduktoro**); **-iva,** conductive.
konduktanc-o, conductance; **komuna—,** mutual c.
konduktor-o, conductor, lead.
konekt-i, to connect; **-o,** connection (*action*); **-aĵo,** connection (*thing*).
konstant-o, constant; **dielektrika—,** dielectric c.
kontakt-o, contact; **ŝova—,** sliding c.; **-a fadeneto por kristalo,** contact wire for crystal, cat-whisker (*see* **Katlipharo**); **-a mikrofono,** c. microphone.
kontinu-a, continuous, direct; **—kurento,** direct current; **—ondo,** continuous (sustained, undamped) wave.
kontraŭpez-o, counterpoise, capacity earth.
kontrol-i, to control; **-panelo,** control-panel.
konvert-i, to convert; **-ilo,** converter (*see* **Konvertitoro**).
konvertitor-o, converter.
krad-o, grid; **-a cirkuito,** g. circuit; **-a rezistanco,** g. resistance (leak); **-a tensio,** g. bias, potential
kristal-o, crystal; **-a detektoro,** c. detector.
krud-a, coarse.
kulombo, coulomb.
kupl-i, to couple; **-o, -ado,** coupling (*action*); **-eco,** coupling (*state*); **apuda -o,** close (tight) c.; **elektromagneta, elektrostatika, -o,** electromagnetic, electrostatic, c.; **fiksa -o,** fixed c.; **indukta -o,** inductive c.; **reakcia -o,** reaction c.; **rezistanca -o,** resistance c.; **termo-o,** thermo-couple; **transformatora -o,** transformer c.; **varia (variigebla) -o,** variable c.; **-ilo,** coupler; **vario-ilo,** vario-coupler; **-ita,** coupled; **induktive -ita,** inductively coupled.
kupr-o, copper; **stanita -o,** tinned c.; **-a pirito,** copper pyrites.
kurent-o, current; **alterna—,** alternating c.; **altfrekvenca—,** high frequency c.; **kontinua,—** direct c.; **malaltfrekvenca—,** low frequency c.; **primaria alterna—,** primary alternating c.; **-a interuptoro,** c. interrupter.
kurv-o, curve (graph); **karakteriza—,** characteristic c.

L

Lamen-i, to laminate; **-ita,** laminated; **-aĵoj,** laminations.
lamp-o, valve (*see* **Valvo**).
laŭt-a, loud; **-igilo, -parolilo,** loud-speaker.
Lejdena botelo, Leyden jar.

M

Magnet-o, magnet; **elektro-a,** electromagnetic.
maksimum-o, maximum.
malalt-a, low; **—frekvenco,** low frequency; **—tensio,** low tension.
manipulatoro, sending key (*see* **Klavo**).

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martela interuptoro, hammer break, trembler.
mast-o, mast; **dismuntebla—,** compound m.; **portebla—,** portable m.
mem-ekscita dinamo, self-excited dynamo.
mem-indukt-o, self-induction.
mem-kapacit-o, self-capacity.
mem-oscil-o, self-oscillation.
mem-skribilo, mem-skribanta aparato, recorder, recording apparatus.
metr-o, meter; **amper-o,** ammeter; **dekre-o,** decremeter; **frekvenc-o,** frequency m.; **galvano-o,** galvanometer; **mikro-o,** micrometer; **miliamper-o,** milliammeter; **ondo-o,** wavemeter; **potencio-o,** potentiometer; **radiogono-o,** radio-i goniometer; **volt-o,** voltmeter.
mezura bobeno, measuring coil.
mikro-, micro-; **-farado,** microfarad; **-henrio,** microhenry; **-metro,** micrometer.
mikrofon-o, microphone; **grajna—,** granular m.; **karbondiska—,** carbon disc m.; **karboncilindra—,** carbon rod m.; **kontakta—,** contact m.; **pulvora—,** powder m.
miliamper-o, milliampere; **-metro,** milliammeter.
minimum-o, minimum.
modul-i, to modulate; **-o, -ado, -eco,** modulation.
Mors-o, Morse; **-a kodo,** M. code.
motor-o, motor; **alternkurenta—,** A.C. m.; **asinkrona—,** asynchronous m.; **indukta—,** induction m.; **-alternatora grupo kun diska sparkilo,** motor-alternator disc set.
mobvobena ampermetro, moving-coil ammeter.
multetaĝ-a, multi-stage (*see* **Multopa**).
multfaz-a, multiphase, polyphase; **—alternatoro,** m. alternator.
mult-opa, multiple, multi-stage; **—agordilo,** m. tuner; **—sendo kaj ricevo,** m. transmission and reception; **—sparkilo,** m. spark gap.
multvibr-ilo, multi-vibrator.
munt-i, to mount; **dis-i,** to dismount.

N

Neakut, flat; **—agordo,** f. tuning.
nefermit-a, open; **—anteno,** o. aerial; **—cirkuito** o. circuit.
negativ-a, negative.
neon-o, neon; **-a tubo,** n. tube.
neŭtrodin-o, neutrodyne.
nod-o, node; **—de intenseco,** current n.; **—de tensio,** potential n.
norm-o, standard, norm; **-igi,** to standardise.

O

Om-o, ohm; **meg-o,** megohm.
ond-o, wave; **amortiza—,** damped w.; **elektromagneta—,** electromagnetic w.; **Hertza—,** Hertzian w.; **kontinua—,** continuous (sustained, undamped) w.; **portanta—,** carrier w.; **propagado de -oj,** propagation of waves; **-metro,** wavemeter; **-a frekvenco,** wave frequency; **sub-eto,** ripple; **sub-eta elimino,** ripple elimination; **-ŝanĝa komutatoro,** wave-changing switch.
orelpec-o, earpiece (*of telephone receiver*); **ĉapo de—,** e. cap.
oscil-i, to oscillate; **ek-i,** to break into oscillation; **-o,** oscillation; **fundamenta -o,** fundamental (natural) o.; **mem-o,** self-oscillation; **-a,** oscillating, oscillation (*adj.*); **-a transformatoro,** oscillation transformer, jigger; **fermita -a cirkuito,** closed oscillating circuit; **nefermita -a cirkuito,** open oscillating circuit; **-ilo,** oscillator (*see* **Oscilatoro**).
oscilator-o, oscillator.

P

Panel-o, panel; **kontrol-o,** control-p.
paralel-a, parallel; **konektita -e,** connected in p.
perikon-o, perikon; **-a detektoro,** p. detector.
permes-o, permission, licence; **riceva, senda—** receiving, transmitting l.
perturb-oj, disturbances.
pil-o, cell; **seka -o,** dry c.; **-aro,** battery.
pirit-o, pyrites; **fera—,** iron p.; **kupra—,** copper p.
plat-o, plate; **—de telefonilo,** diaphragm of telephone receiver; **-a cirkuito,** plate circuit.
polus-o, pole; **-a,** polar, pole (*adj.*); **du-a,** double-pole; **unu-a,** single-pole.
porcelan-o, porcelain.
potenc-o, power; **faktoro de—,** power factor.
potenciometro, potentiometer.
pozitiv-a, positive.
primari-o, primary; **eliro de—,** outer p.; **eniro de—,** inner p.
propagado de ondoj, propagation of waves.
proporci-o, proportion, ratio.
pulvora mikrofono, powder microphone.

R

Radi-o, radio; **-amanto,** r. lover, "fan"; **-amatoro,** r.-amateur; **-ejo, -o-stacio,** r. station; **-isto,** r. professional; **-ulo,** r. user; **-o-frekvenco,** r. (high) frequency; **-o-telefonio,** r.-telephony; **-o-telegrafio,** r. telegraphy; **-i, -adi,** to radiate; **-ado,** radiation; **-anta,** radiating.
radiogoniometr-o, radiogoniometer.
rapid-eco, velocity.
reakci-o, reaction, regeneration, feed-back (*see* **Regenero**); **-a kuplo,** r. coupling; **super-o,** super-regeneration.
reaktanc-o, reactance.
refleks-a, reflex.
regener-i, to regenerate; **-o,** regeneration, reaction, feed-back; **super-o,** super-regeneration (*see* **Reakcio**).
registr-i, to log, to register; **-o-libro,** log-book.
rejet-i, to reject; **-a,** rejector (*adj.*).
rektif-i, to rectify; **-o, -ado,** rectification; **-ilo,** rectifier (*see* **Rektifikatoro**).
rektifikator-o, rectifier.
relaj-o, relay; **alt-tensia—,** high tension r.; **—de la manipulatoro (senda klavo),** key r.; **-i,** to relay.
rendiment-o, efficiency.
reostat-o, rheostat, variable resistance; **filamenta—,** filament r.; **starta—,** starting resistance; **—de kampo,** regulating resistance.
resonanc-o, resonance; **-a kurvo,** r. curve.
resonator-o, resonator.
rezistanc-o, resistance; **alta—,** high r.; **izola—,** insulation r.; **krada—,** grid r. (leak); **malalta—,** low r.; **varia (variigebla)—,** variable r.; **-a amplifikatoro,** r. amplifier; **-a kapacito,** r. capacity; **-a kuplo,** r. coupling.
ricev-i, to receive; **-o, -ado,** reception; **-anto, -isto,** receiver (*person*); **-ilo, -aparato,** receiver, receiving apparatus, r. set; **kompensita -ilo,** balanced receiver; **-ilo por kontinuaj ondoj,**

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continuous wave receiver; **-ila aranĝo,** receiver arrangement.
rotor-o, rotor.

S

Saturo-eco, saturation.
sekundari-o, secondary; **eliro de—,** outer s.; **eniro de—,** inner s.
selekt-i, to select; **-iva,** selective; **-iveco,** selectivity.
send-i, to transmit, to send; **-a,** transmitting (*adj.*); **-a klavo,** sending key; **-o, -ado,** transmission; **-anto, -isto,** transmitter (*person*); **-ilo, -aparato,** transmitter, transmitting apparatus, t. set; **dis-i,** to broadcast (*see* **Brodkasti**); **el-i,** to emit; **el-o,** emission (*see* **Emisio**).
senfaden-a, wireless; **—telegrafio, telefonio,** w. telegraphy, telephony; **-isto,** w. operator.
seri-a, series (*adj.*); **konektita -e,** connected in s.
signal-o, signal; **vok-o,** call-sign; **kompensitaj (ekvilibritaj) -oj,** balancing signals.
silent-igilo, damper.
sinkron-a, synchronous; **—sparkilo,** s. discharger.
sintez-a, synthetic.
sintoni-o, syntony.
sintoniz-i, to syntonise, to tune (*see* **Agordi**); **-o,** syntonisation; **-ita sistemo,** tuned system.
skrib-i, to write; **-ilo, -anta aparato,** writing apparatus; **mem-ilo, mem-anta aparato,** self-recorder, self-recording apparatus
sold-i, to solder.
sonfort-igilo, note magnifier, L.F. amplifier.
spark-o, spark; **estingita—,** quenched s.; **—de rompo,** break s.; **-a distanco,** sparking distance; **-ilo,** spark gap, discharger; **asinkrona -ilo,** asynchronous d.; **estinga -ilo,** quenched s.g.; **multopa -ilo,** multiple s.g.; **turna -ilo,** rotary s.g.
spil-i, to tap, to draw from (*see* **Tapi**); **-aĵoj,** tappings.
spindel-o, spindle.
spul-o, coil (*see* **Bobeno**).
stabil-a, stable, firm; **-eco,** stability; **-igilo,** stabiliser.
staci-o, station.
stang-o, pole, staff; **apartiga—,** spreader.
start-i, to start; **-a reostato,** starting resistance; **-ilo,** starter.
stator-o, stator.
streĉ-o, stress; **dielektrika—,** dielectric s.
super, above, super; **-heterodino,** super-heterodyne; **-regenero,** super-regeneration; **-sona,** supersonic.

Ŝ

Ŝalt-i, to switch (*general term*); **-ilo,** switch; **-a tabulo,** switch-board.
ŝarĝ-i, to charge; **-a interuptoro,** charging switch; **-o,** charge; **-tro-o,** overload.
ŝelak-o, shellac.
ŝirm-i, to screen; **-ita,** screened.
ŝova kontakto, sliding contact.
ŝtopi-, to plug; **-ilo,** plug; **bobena -ilo,** coil plug; **en-i,** to plug-in; **en-a bobeno,** plug-in coil.
ŝunt-o, shunt; **altindukta—,** highly inductive s.; **neindukta—,** non-inductive s.

T

Tap-i, to tap, to take a tapping; **-aĵoj,** tappings.
telaŭtograf-o, telautograph.
telefon-o, telephone; **-ilo, -ricevilo,** t. receiver.
telefoni-o, telephony.
telegraf-o, telegraph.
telegrafi-o, telegraphy.
tensi-o, tension, voltage, potential; **alta—,** high t.; **malalta—,** low t.; **nodo de—,** potential node; **ventro de—,** potential loop; **alt -a relajo,** H.T. relay.
ter-o, earth, ground; **-a konektaĵo,** e. connection.
termion-a, thermionic; **—valvo,** t. valve.
termoelektr-a, thermoelectric.
termokupl-o, thermo-couple.
Tesla bobeno, Tesla coil.
tetrad-o, tetrode, four-electrode valve.
tikl-ilo, tickler.
trafpov-o, range.
transform-i, to transform; **-ilo,** transformer (*see* **Transformatoro**).
transformator-o, transformer; **altfrekvenca—,** H.F. t.; **malaltfrekvenca—,** L.F. t.; **aerkerna—,** air core t.; **altproporcia—,** high ratio t.; **malaltproporcia—,** low ratio t.; **enŝtopa—,** plug-in t.; **oscila—,** oscillation t.; **-a kuplo,** t. coupling.
triod-o, triode, three-electrode valve.
troŝarĝ-o, overload.
tub-o, tube (*see* **Valvo**).
turbo-alternatoro, turbo-alternator.
turbo-interuptoro, turbo interrupter.
turna spark-ilo, rotary spark gap.
turnboben-o, rotor (*see* **Rotoro**).

U

Ulul-i, to howl; **-ado,** howling.

V

Vaku-o, vacuum; **-a tubo,** v. tube.
valor-o, value; **efika—,** root mean square (value).
valv-o, valve; **amplifa—,** amplifying v.; **detekta—,** detecting v.; **du-, tri-, kvar-elektroda—,** two-, three-, four-electrode v.; **hela—,** bright (emitter) v.; **malhela—,** dull (emitter) v.; **-a detektoro,** v. detector; **-a amplifikatoro,** v. amplifier.
vari-i, to vary; **-a, -iga,** variable; **-o-kuplilo,** vario-coupler.
variometr-o, variometer.
varmfaden-a, hot-wire (*adj.*); **—ampermetro,** h.w. ammeter; **—voltmetro,** h.w. voltmeter.
vat-o, watt; **kilo-o,** kilowatt.
velk-i, to fade; **-o,** fading.
ventro de intenseco, current loop.
ventro de tensio, potential loop.
vernier-a, vernier.
vibr-i, to vibrate; **-ilo,** vibrator; **mult-ilo,** multi-vibrator.
voj-o, way; **du-a,** double-way, double-throw; **unu-a,** single-way, single-throw.
vok-i, to call; **-signalo,** call-sign.
volt-o, volt; **-metro,** voltmeter; **varmfadena -metro,** hot-wire voltmeter; **alternkurenta -metro,** A.C. voltmeter; **kontinukurenta -metro,** D.C. voltmeter.

Z

Zum-i, to buzz; **-ilo,** buzzer.

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Letters of interest to experimenters are always welcome. In publishing such communications the Editors do not necessarily endorse any technical or general statements which they may contain.

Rectification—A Reply.

The Editor, E.W. & W.E.

DEAR SIR,—I should like to reply to the two correspondents who commented upon my article on "Rectification," published in the December issue. The low anode current is naturally due to the relatively low filament current employed in the Ora valve. The suggestion of substituting a broadcast station would not, I am afraid, give the satisfactory results anticipated by Mr. H. Emmons, but I hope to extend these experiments in the near future by employing ordinary, interrupted C.W. and specially-modulated C.W., when I trust the results will be made public and comparisons be made.

With reference to the cases quoted by Mr. Emmons, I should be glad to know if the better results were judged qualitatively or quantitatively, and if grid-leak resistance values were measured before and after the experiment, and also whether account was taken of the insulation resistance between valve-holder electrodes, as mentioned in my article of the January issue?

I would refer Mr. Smith to my remarks above, but fail to appreciate his sentence concerning the obvious effect of the wave-length on grid-leak values. The wave-length employed was above broadcast values—between 600 and 700—but the determination of optimum resistance values depends on the grid characteristic, as ably illustrated in the article "The Perfect Set," in the November issue of E.W. & W.E.

H. J. BARTON CHAPPLE.

Bradford Technical College.

Grid and Anode Rectification.

The Editor, E.W. & W.E.

DEAR SIR,—The disparagement of the valve as an "anode" detector on the score of inefficiency reaches its climax in Mr. H. J. Barton Chapple's article in your December issue. It is to be noted, however, that his conclusions are based on the use of the same valve for both methods. The Ora is quite suited to the cumulative grid-detecting system, but of all the hundred or so types on the British market it would be a problem indeed to choose one less suited to anode rectification. The 5—1 signal strength ratio would be much nearer the 3—2 mark if the valves were chosen for their work. Of course, the output instrument (transformer primary, etc.) must be suited to the comparatively high impedance of the anode detecting valves—comparative, that is, to that of grid detectors. L.F. transformers with primaries of 60 and more henries are easily obtainable, and under the best conditions in each case, anode detecting does not fall very far behind the grid method in strength (of little importance, after all), and the tonal superiority of the former is unquestioned in the case of telephony.

Your note at the foot of p. 186 seems to imply that the R.S.G.B. is more or less to blame. Now I wonder what *would* be the reply of either of the Services if the R.S.G.B. offered such assistance as that accepted from the American amateurs? An iceberg would probably arrive at 53, Victoria Street, carefully packed! Besides, the Post Office would probably demand a deposit of £103 for licences before opening a prolonged and abortive discussion, extending long after the period required had elapsed.

L. J. VOSS.

Plymouth.

H.F. and L.F. Amplification.

The Editor, E.W. & W.E.

DEAR SIR,—Your remarks concerning the choice of H.F. and L.F. for short-wave DX work in your "Editorial Views" in a recent issue of E.W. & W.E. are somewhat misleading. To the inexperienced amateur it would appear that for efficient two-way DX working an H.F. amplifier should be used, and that for reception purposes only one is able to dispense with the H.F. amplifier and to use L.F.

Now let us consider what is required by the transmitting amateur and the receiving amateur. In the first case the receiver must be sensitive, selective and capable of quick searching; and in the second case it must have precisely the same properties.

There is no reason why the receiver should be different in these two cases. The transmitting experimenter must have a receiver capable of quick searching, since the fellow at the other end may wish to change his wave-length. When the operator closes down to one station, he always listens to see if any other stations are calling him, and quick searching is again necessary.

One type of receiver is needed. The supersonic heterodyne is too expensive for most of us, and the ordinary H.F. amplifier is dismissed as being incapable of quick searching.

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We are left with the detector and L.F. set. Examples of the sensitivity and selectivity obtainable in this type are met with daily, and it cannot be said that it is difficult to control.

Incidentally, Mr. Hogg informs me that he is now using a detector and one L.F. in place of his old H.F. and detector. For the past two months I have been doing two-way DX work of the usual standard, and have not experienced even the slightest trouble with the receiver.

These facts, together with the other evidence, help to prove that for either two-way communication or reception only the detector and L.F. type of receiver is the best, from the experimenter's point of view, for short-wave, DX work.

S. K. LEWER.

West Hampstead.

[These arguments seem to us quite unconvincing. In our opinion, the "best" type of receiver for logging call signs will be of quite a different type from the "best" for two-way working. This correspondence is now closed.—ED., E.W. & W.E.]

Efficiency of the Counterpoise.

The Editor, E.W. & W.E.

DEAR SIR,—I was much interested in Mr. M. C. Ellison's article, "The Efficiency of the Counterpoise," appearing in your January issue. May I point out one little fallacy? Throughout the article Mr. Ellison states that his radiation was so-and-so many ampères. A high-frequency generating system connected to an aerial does not radiate ampères; it radiates watts.

Not for one moment do I imagine Mr. Ellison is ignorant of this simple fact, but there is a great tendency by experimenters to express their radiation in ampères. It is a very minor point, but one finds it so constantly being used that I feel this is an excellent opportunity "to drop a gentle hint."

Mr. Ellison says he thinks the only apparent advantage of the counterpoise is to reduce the fundamental wave-length of the aerial. Besides this important fact, surely one of the greatest advantages of the counterpoise, from an amateur point of view, is to reduce the ground loss resistance of the whole radiating system?

Hove. DALLAS G. BOWER.

The Editor, E.W. & W.E.

DEAR SIR,—In the January issue of E.W. & W.E. there is an article by Mr. M. C. Ellison about "The Efficiency of the Counterpoise," in which he makes the curious statement that the counterpoise system is less efficient than the earth system.

Of course, this cannot be the fact, especially if the counterpoise is well designed. Not only is the fundamental wave-length reduced, as mentioned by the author, but—and here the gain lies—the total loss-resistance of the aerial system is reduced. At the same time, the radiation resistance is very little (if at all) decreased; it may even be greater than before. Thus the aerial efficiency, *i.e.*, the ratio between the radiation resistance and the total resistance, will be increased.

If we wish to compare the efficiencies of the systems mentioned above we have to supply them with the same amount of power, and that so as to give different ammeter readings, for if we do not know the maximum points of aerial current, the ammeter tells us nothing.

Finally, the author's way of comparing the systems by measuring the voltage induced in a tuned coil in the vicinity of the aerial is wrong. Near the aerial the fields may have any direction and any value; it may even happen, as in the author's case, that the earth system will give larger readings on the voltmeter. But make the same measurements, say, 15 wave-lengths from the aerial, where the geometric dimensions of the aerial can be neglected!

Some months ago I was experimenting on these lines and fully proved the quite enormous gain in efficiency by the use of a counterpoise instead of the normal earth. Wave-lengths, 80-150 metres

Stockholm. GUSTAV LAMM (Swedish SM27).

"Poaching."

The Editor, E.W. & W.E.

DEAR SIR,—I should be obliged if your valuable columns could be used to draw attention to the fact that from reports received some person is making illicit use of our call 2AW.

This station has not operated since March last, and will not do so for a month yet.

From the regularity of reports the Birmingham area would be indicated, but reports have also been received from the Department of Moselle, France.

Wakefield. H. H. BURBURY.
Crigglestone, Wakefield.

Some Suggestions.

The Editor, E.W. & W.E

SIR,—In the issue of your magazine for October last and at the conclusion of the first "instalment" of "The Perfect Set" series appeared a very wise remark that, "In our opinion there is too much written about detailed construction these days, and not enough about principles, and we have endeavoured to fill in some of the gaps in the latter division." This seems to me to be the crux of the matter in so far as I myself am concerned and, I should imagine, as far as a good number of your readers are likewise concerned. Now, the article, "An Easy Way to Calculate Circuits," by P. K. Turner in your November number is a step, or perhaps two steps, in the right direction; however, I am only fit, mentally, to take my "maths" in small doses, and would appreciate a series of articles on the same subject, not quite so condensed, perhaps, but a little extended in scope, both upwards and downwards. What beginners must have, if they are to learn anything, is the reason why for everything they do, and the reason why they should not do a lot of the things they do. I am very much obliged to you for bringing to my knowledge the workings of the Dewey system.

Again, it seems to me that amateurs will never be able to do any serious work unless they are in the possession of measuring instruments; you have

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very nobly stepped into the breach with your calibration scheme; most of us have only the money to purchase one decent measuring instrument, if that.

Now, is it practicable for you to publish a series of articles on the measurement of various quantities, not the condensed type of article that only the initiated can understand, but starting with one fairly accurate instrument, such as a sensitive galvanometer, to show us *in detail* how, by admixture of various condensers, resistances, etc., to make a series of fairly accurate measurements of useful quantities, teaching us to check our results somehow or other, and not forgetting to constantly din into our fuddled brains the deductions we should draw. Please do not think that I am trying to teach you your business; but I am simply trying to ask you to do something to help the advancement of Science and to do something for us that no other radio journal in this country has yet done or ever will do. Text-books always assume that one lives in a well-ordered laboratory, and do not show us how to allow for the errors that are always present when amateurs use measuring instruments.

Thanking you for your excellent magazine.

"BEGINNER."

Monmouthshire.

[We welcome letters such as the above, for they indicate a means by which we can serve best the interests of our readers. All suggestions receive careful consideration and, whenever sufficient interest is shown, we endeavour to publish articles dealing with the subjects desired.—ED., E.W. & W.E.]

Esperanto *versus* Others.

The Editor, E.W. & W.E.

DEAR SIR,—In describing the new high-power transmitter at CKAC (Montreal) in your January issue, mention is made of the use by this widely-heard broadcasting station, of an auxiliary language that is other than "Esperanto."

As for some years I too supported Esperanto, but like CKAC am now of the opinion that the alterations effected in its newer form are of the greatest importance, it may be of interest to enumerate the basis of such claims, so far as a short letter will permit.

The first appears in its name: Registered as "The International Language of the Delegation," because it was unanimously adopted and launched by "The International Delegation (of Linguistic Savants) for the Adoption of an Auxiliary Language" and because it is in fact "International" in the sense that all roots used are international ones. "Ido" is used as an abbreviation much as "Espo" is for Esperanto. The word "Ido" is merely an Esperanto suffix serving to indicate a newer form of Esperanto.

"Ilo" is another short name that stands for "International Language (Official)," meaning: "of the Delegation."

[Here followed some detailed comparisions of Ido and Esperanto, which we have omitted. See our note below.—ED., E.W. & W.E.]

The "International Language of the Delegation" is not the product of a single individual or the property of a commercial concern, but claims to be a scientific auxiliary evolved by linguistic savants from the six leading languages, simple, euphonious, regular, having the exactitude of mathematics yet speedy in transmission, and applicable to radio without alteration.

E. H. TURLE, A.M.I.E.E.

London.

[We regret to have to "cut" the letter of a correspondent, but for reasons given in our "Editorial Views," we do not propose to open our columns to any discussion on the comparative, merits from the philological point of view of various international languages —Ed. E.W. & W E.]

More "Effective Transmission."

The Editor, E.W. & W.E.

SIR,—In your issue of December last you published a letter from Mr. E. H. Robinson dealing with my "Effective Transmission" articles. I will reply to his criticisms in the order in which he made them.

A high resistance H.F. circuit will not, and cannot, flatten tuning if both plate and filament supplies are quite pure, but will do so, for the reasons Mr. Robinson gives amongst others, if any modulation is present, as is nearly always the case to some extent in practice. But, in any case, no one, I suppose, will advocate high-resistance coils.

On the question of the side-bands of raw A.C. Mr. Robinson is quite right. I had forgotten, at the moment of writing, the fact that the valve must stop oscillating every other half-cycle. The side-bands produced would, I should imagine, be infinite.

As to the question of harmonics, Mr. Robinson has mis-read the article. He will find that I only condemned harmonics which could be heard by a remote receiver, and are therefore present in the aerial. Harmonics must, of course, be produced in the closed circuit if any sort of efficiency is to be obtained (another reason, by the way, for a low-resistance closed circuit, since we want to keep these components wattless).

Finally, I hope Mr. Robinson does not class me with the "many amateurs who despise theory as not in agreement with practice," as he seems to suggest! If so, he's wrong—both in theory and practice! By the way, the letter below Mr. Robinson's accuses me of a statement (about condensers) which was actually made by another contributor. Sorry, wrong number! Try 2DX!

Wimbledon Park. HUGH H. RYAN.

A New Call Sign.

The Editor, E.W. & W.E.

DEAR SIR,—Please allow me to advise you that the transmitting call sign 2IH was allotted to me some time ago, and I should be pleased if you could publish this fact and also alter your list of call signs.

I might add that I shall be at all times pleased to receive reports on my transmissions.

Wishing your periodical every success.

Riddlesden. H. HILEY.

Nr. Keighley.

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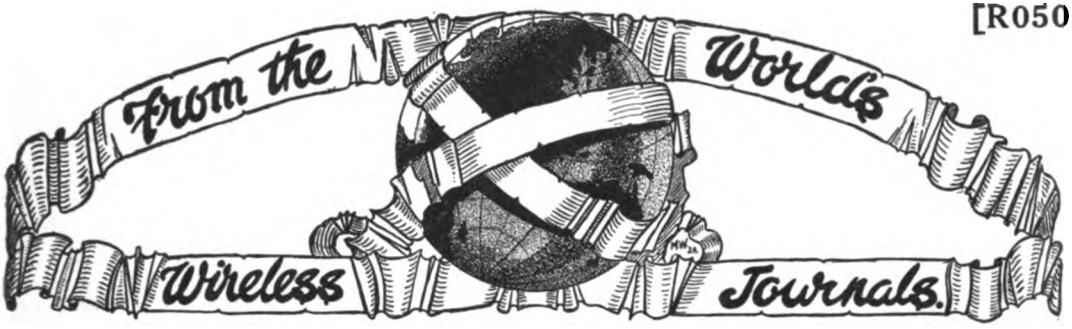
[R050



R100.—GENERAL PRINCIPLES AND THEORY.

R112·1.—On the Radiation Resistance of a Simple Vertical Antenna at Wave-Lengths Below the Fundamental.—Stuart Ballantine (*Proc. I.R.E.*, Dec., 1924).

R113·4.—Sir Joseph Larmor's Theory: Why Wireless Electric Rays Can Bend Round the Earth.—G. W. de Tunzelman (*Electn.*, Jan. 9, 1925).

Summary of a theory which has been recently developed by Sir Joseph Larmor to explain the bending of radio waves round the surface of the earth. The theory, in some respects, is similar to that suggested earlier by Eccles—inasmuch as an ionised upper atmosphere is involved—but also attempts to put the matter on a tangible scientific basis. The chief feature of the theory is the refraction which may occur in an ionised atmosphere owing to the different velocity of electromagnetic waves in ionised and un-ionised atmospheres.

R121.—On the Optimum Transmitting Wave-length for a Vertical Antenna Over a Perfect Earth.—Stuart Ballantine (*Proc. I.R.E.*, Dec., 1924).

R131.—The Inter-Electrode Capacities of a Valve.—H. J. Barton Chapple, Wh.Sch., B.Sc. (Hons.) (*Exp. W.*, Jan., 1925).

Some measurements on the actual inter-electrode capacities of various types of valve.

R200.—MEASUREMENTS AND STANDARDS.

R210.—Ondamètre d'Absorption Pour Poste Récepteur.—M. Clayeux (*Onde Elec.*, Dec., 1924).

The wave-meter described comprises simply a variable tuned circuit, and is intended to work in conjunction with a receiving set. The means of indicating resonance between the wave meter and the receiver are described in the article.

R210.—Standing Waves.—Gustav Lamm and Edward Graham (*W. World*, Dec. 31 and Jan. 7, 1924).

Description of the Lecher wire arrangement for making absolute determinations of wave-length on waves of the order of 10 metres or less. A practical method of laboratory procedure is given.

R210.—Correction Factor for the Parallel Wire System Used in Absolute Radio Frequency Standardisation.—August Hund (*Proc. I.R.E.*, Dec., 1924).

Errors which may occur in Lecher wire measurements and a correction factor to apply.

R210.—Wave-meters.—L. B. Turner, M.A., M.I.E.E. (*W. World*, Dec. 17 and 24, 1924.)

A paper read before the Radio Society of Great Britain dealing with various methods of arriving at frequency and wave-length in radio work. The different methods of absolute measurement are summarised: namely, natural frequency of oscillatory circuits, oscillograph records, generation by H.F. alternator, Lecher wires and multivibrator methods.

Comparison of frequencies and forms of practical calibrated instruments are next dealt with. This involves a detailed discussion on heterodyne, buzzer and detector wave-meters, and means of indicating resonance. The paper concludes with some practical points on the design of wave-meters and wave-length standards for everyday use. It is of interest to note that the author of the paper prefers a variometer and fixed condenser to the usual combination of a variable condenser and fixed inductance for wave-meter purposes.

R240.—Sur l'Absorption des Ondes Courtes J. Granier (*Onde Elec.*, Dec., 1924).

Experiments to determine the resistances and dielectric losses of various substances on oscillatory currents of frequencies of the order of 10^{-8} (3 metres wave-length). A 3-metre oscillator is loosely-coupled to a closed oscillatory circuit containing a fixed inductance, a variable condenser, a known variable resistance and an H.F. current-indicator. The measurement of resistance of a conductor is

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effected by first inserting the conductor in the circuit and bringing the circuit into exact resonance with the oscillator by means of the variable condenser. Next the conductor under measurement is replaced by the known resistance, which is adjusted until the same current is obtained at resonance as before. For dielectrics these are made to replace the condenser, by again replacing the dielectric under measurement by an air condenser of low losses and re-adjusting the resistance to give the same current, one arrives at the equivalent series resistance corresponding to the dielectric loss.

The H.F. currents being small require an indicating instrument of greater sensitivity than the usual hot-wire ammeter, and the instrument actually used is interesting for its cheapness and ingenuity. An ordinary low consumption 1 c.p. pocket lamp bulb is included in the H.F. circuit so that its filament becomes heated to a greater or less extent by the H.F. currents flowing through it; this causes a change in the D.C. resistance of the bulb which is recorded in a Wheatstone Bridge balanced for D.C., of which the bulb forms one arm. The arrangement is, in effect, a simple bolometer bridge.

The results of measurements made at the above ultra high frequency are interesting. The skin effect of iron is materially exaggerated by the permeability of this metal, and its hysteresis provides a further source of loss. An iron wire 1 mm. in diameter was found to have a resistance of 20 ohms per metre. Tinned copper wire was found to have a resistance 2·8 times that of the bare wire, as the pronounced skin effect causes the major part of the current to flow through the surface layer of tin and not through the body of the copper. Galvanised iron would be a better conductor than tinned copper, since zinc is a better conductor than tin.

The conductivity of a wire immersed in electrolytes of various strengths showed some interesting effects. If the wire was surrounded by electrolyte of only slight conductivity, most of the current was carried by the wire. As the conductivity of the electrolyte was increased, a greater proportion of the current travelled via the electrolyte, while the net resistance of the system was increased. Thus the resistance of a wire 3 cm. long and 0·1 cm. in diameter, immersed in 0·9 per cent. sulphuric acid, showed a resistance of 2·2 ohms, but when immersed in 20 per cent. sulphuric acid, showed a resistance of 4·8 ohms.

The power factor of water as a dielectric in a condenser was measured using distilled water, river water and sea water respectively. With the latter condenser action disappeared as far as the tuned circuit was concerned. Power factor measurements were also made for a number of common dielectrics, and although the figures obtained are not claimed as being accurate absolute values, it has been possible to arrange a number of these substances in a distinct order of merit. Paraffin and mica are easily the best, while dry brick and dry earth come next. These are followed by glass and waxed paper, while below these in the list ebonite ties with ordinary brick! Moist things, like leaves and damp earth, are the worst dielectrics. The author of the article discusses the possible bearing of his observations on ultra-short wave transmission and explains the serious effect of the presence of poor dielectrics in short wave apparatus.

R250.—Measuring very small R.F. Currents. —J. H. Turnbull (*Q.S.T.*, Jan., 1925).

The arrangement described suffices for the measurement of high-frequency currents of the order of one-tenth of a milliampère. It consists of a hard, two-electrode valve (or an ordinary triode with grid and anode connected together), in the anode circuit of which is included a milliammeter and a source of fixed potential.

An ammeter is also provided in the filament circuit, and a curve is plotted showing anode current against various heating currents through the filament. The small H.F. currents to be measured are passed through the filament (which has been previously adjusted to a convenient brightness), and the change in emission as indicated by the plate milliammeter is noted. From the calibration curve the superimposed H.F. current through the filament is deduced. Of course, suitable chokes have to be provided to prevent the H.F. currents passing through the filament heating battery.

R281.012.5.—Electrical Constants of Dielectrics for Radio-Frequency Currents.—R. V. Guthrie, Jr. (*Proc. I.R.E.*, Dec., 1924).

We hope to publish an abstract of this in our next issue.

R300.—APPARATUS AND EQUIPMENT.

R321 : R326.—Some Experiments with Aerial and Earth Systems for Reception. —R. L. Smith-Rose, Ph.D. and F. M. Colebrook, B.Sc. (*Exp. W.*, Jan., 1925).

The results of some long-needed precise experiments on the relative merits of various aerial earth and counterpoise systems for reception on wave-lengths in the region of 300 metres.

R330.—Moderne Empfängröhre.—H. Rukop (*Telefunken-Zeitung*, Oct., 1924.)

A general and historical article on German valve technology with particular reference to the Telefunken range of products. Conditions governing the optimum size of filaments, dull-emitting filaments, etc., are discussed.

R334.—La Lampe à Quatre Electrodes.—H. Nozières and P. Giroud (*Onde Elec.*, Dec., 1924).

The purpose and properties of the use of an auxiliary grid in a thermionic valve are explained. The idea is that of Langmuir who took out a patent in 1913. The action by means of which the auxiliary (internal) grid reduces the space charge, and the practical advantages accruing therefrom, are explained with the aid of curves and diagrams.

R355.52.—Mercury Arc Rectifiers.—Earl D. Smith (*Q.S.T.*, Jan., 1925).

Short account of some experiments on the use of a mercury arc to produce H.T. plate supply for a valve transmitter. Results were obtained but were not altogether satisfactory because the power required to keep the mercury arc alight

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was large compared with the power required for the transmitter. It is not worth attempting to use an ordinary mercury arc rectifier for inputs of anything less than 100 watts to the transmitter.

R374.—A TEST FOR CRYSTALS.—P. K. Turner (*Exp. W.*, Jan., 1925).

Details of a method of making quantitative measurements on a crystal receiver for the purpose of specifying the merits of various crystals. The means by which the difficult problem of measuring H.F. power of a few microwatts has been solved are of particular interest.

R374—375.—BEITRÄGE ZUR KENNTNIS DER DETEKTORWIRKUNG (CONTRIBUTION TO THE KNOWLEDGE OF DETECTOR-ACTION).—Georg Hilpert (*Telefunken-Zeitung*, Oct., 1924).

This article describes some observations on the thermoelectric and detecting properties of loose contacts between metallic wires. Rectification falls into two distinct classes, namely, that due to pure valve action and that which is occasioned by curvature in the voltage-current characteristic of some system. An interesting fact is pointed out; that if a condenser be inserted in series with an ordinary detector signals are still audible in a pair of telephones, although all D.C. current, except that required for the initial charging of the condenser, is stopped. This is due to the difference in wave-form produced on the positive and negative half-cycles of the H.F. voltage across the condenser, which causes alternate half-cycles to affect the telephones to a different degree. The chief interest of the article lies in the experiments with junctions of two pieces of the same metal. If the ends of two platinum wires are allowed to touch and the junction thus formed symmetrically heated in a flame no thermoelectric current can be detected in any circuit of which the junction forms part. This, of course, is to be expected. If, however, the flame is shifted to one side of the junction so that the temperatures either side of the point of contact are not symmetrical, then a distinct thermoelectric current may be registered. This effect is much more pronounced if copper wires are used instead of platinum. In this case a film of copper oxide between the contact points is supposed to account for the observed phenomenon; the junction actually consisting of two copper to copper oxide junctions in opposition. If placed symmetrically in a flame both junctions will attain the same temperature and will, therefore, generate equal and opposite thermo-E.M.F.'s. By holding flame to one side the temperature conditions in the two junctions are different, different thermo-E.M.F.'s are produced and a resultant current flows. Now the thermoelectric E.M.F. of a couple is seldom a linear function of the temperature over any large range of temperature, so that junctions of the kind under consideration may have conductivity characteristics similar to those exhibited by crystal detectors.

Experiments were made using asymmetrically-heated junctions as detectors for wireless signals. For convenience the heating was effected by means of an auxiliary spiral carrying an electric current. It was found that with several different substance for the junction signals from a neighbouring transmitting station could be distinctly heard in a pair of telephones. For any one combination there was a definite temperature which gave the best results. The outputs on a presumably constant signal are reproduced below, the figure for a good pyrites detector being included as a standard for comparison.

Metal point—Pyrites	1 000
Copper—Copper	190
Constantan—Constantan ..	105
Platinum—Platinum	9
Iron—Iron	2
Carbon—Carbon	2
Copper—Flame—Copper ..	1

It is pointed out that one of the conditions for detection with such couples is that the contact resistance must not be too low. Also, the contact pressure must not be too heavy or the oxide film may be pierced. We are rather left in doubt however as to what intermediate film can exist in the case of the carbon-carbon contact, but still the writer does not guarantee the purity of his materials further than they are ordinary commercial samples.

R376.—LOUD-SPEAKERS.—Capt. H. J. Round, M.I.E.E. (*W. World*, Dec. 17, 1924).

Description of a loud-speaker designed on analogous lines to the Sykes-Round magnetophone. The speech-currents energise a light coil of wire held by a special diaphragm in a powerful magnetic field, the diaphragm having a natural period of vibration of about 1/250 of a second. It is stated that this type of loud-speaker may be constructed for very loud reproduction. Some of the difficulties experienced in operating public address systems are briefly mentioned

R600.—STATIONS: DESIGN, OPERATION AND MANAGEMENT.

R610.—THE HIGH POWER STATION AT MALABAR, JAVA.—Dr. C. J. de Groot (*Proc. I.R.E.*, Dec., 1924).

A most interesting technical description of one of the world's great high-power arc stations. A good example of modern high-power radio-engineering practice.

R610.—SHORT-WAVE RADIO BROADCASTING.—Frank Conrad (*Proc. I.R.E.*, Dec., 1924).

The technical history of the KDKA short-wave transmitter, which, it may be recalled, began its career under the amateur call-sign of 8XK.

R610.—BROADCAST TRANSMITTING STATIONS OF THE RADIO CORPORATION OF AMERICA.—Julius Weinberger (*Proc. I.R.E.*, Dec., 1924.)

Technical description. The reader is referred to the original paper for details.

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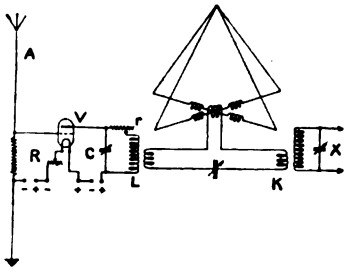
(The following notes are based on information supplied by Mr. Eric Potter Patent Agent, Lonsdale Chambers, 27, Chancery Lane, W.C.2.) **[R800**

DIRECTIONAL RECEPTION.

(*Application date, May* 18, 1923. *No.* 220,392.)

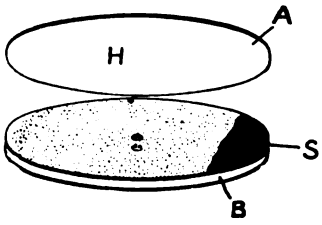
British Patent No. 220,392 granted to G. M. Wright and L. D. Hill, describes a directional reception scheme shown in the accompanying diagram. It will be seen to consist in combining a non-directional aerial with a directional aerial in the following manner. A non-directional aerial A is damped by means of a resistance R, which is adjusted to give the aerial its critical damping. This resistance is connected across the grid and filament of a valve V, in the anode circuit of which there is an inductance L, the impedance of which is small compared with that of the valve. This impedance can be varied by means of a resistance *r* and a capacity C. This inductance L is coupled magnetically to the search coil of the goniometer. The search coil circuit contains an inductance K which is coupled to a receiving circuit X. The valve V must have a straight characteristic, and the use of a small transmitting valve is recommended with a resistance in the anode circuit. The operation of the scheme is as follows: Arriving signals set up E.M.F.'s in the aerial A, which are in phase with the field. As the aerial is damped the potentials set up across the resistance R are also in phase. Now as the impedance of the anode coil is small compared with that of the valve the current in the coil is in phase with the potentials across R, so that the induced E.M.F. is 90 degrees out of phase with the field of the arriving signal. Turning now to the frame aerial the E.M.F. is 90 degrees out of phase with the field and as the impedance of the loop circuit is substantially inductive the current is 180 degrees out of phase with the E.M.F., and hence the phase difference between the E.M.F. in the search coil circuit and the field of the arriving signal is 90 degrees. It will therefore be seen that it is possible to obtain a balance between the open and loop aerials, the usual cardioid diagram being obtainable. An advantage of the system is that a heart-shape can be obtained for long wave-lengths on small aerials.



A BUILT-UP DIAPHRAGM.

(*Application date, June* 20, 1923. *No.* 222,180.)

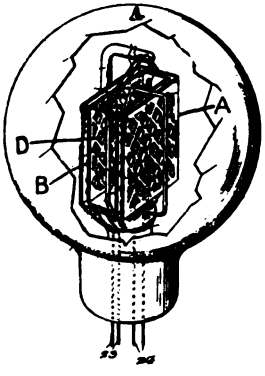
The Radiotive Corporation describe in the above patent a method of diaphragm construction. The diaphragm is built up from two celluloid discs A and B, together with a silk centre S. The silk is spread with a mixture of powdered shellac and mica and the whole is placed under pressure and heated. This causes the shellac to melt and forms with the mica a plastic mass which hardens on cooling. The discs are provided with a hole H, to which a lever connected to an armature is attached. The specification describes several modifications and provides for the corrugation of the diaphragm.



ELECTRODE CONSTRUCTION.

(*Application date, August* 17, 1923. *No.* 219,823.)

G. la Vere Geisley and F. W. Brown claim in the above patent a form of electrode construction shown in the accompanying diagram. The chief feature of the invention lies in the type of anode and grid which are employed. It will be noticed that the grid B has in it a number of diamond-shaped openings D. These openings coincide with diamond-shaped indentations in the anode A. The grid and anode are assembled so that the indentations in the anode project inwards and are exactly opposite the openings in the control electrode. The object of the invention is to provide a valve which shall be perfectly rigid and as free as possible from microphonic or mechanical noise. It is also stated that this method of construction enables a valve to be produced which can have a high voltage and current output.



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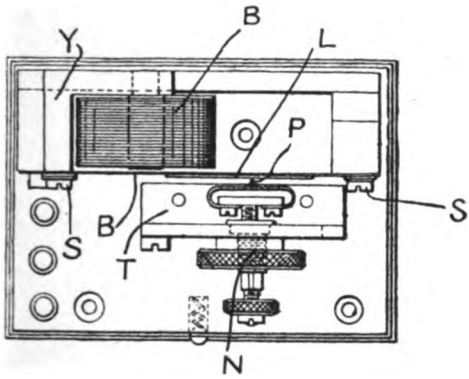
A TUNED INTERRUPTER.

(*Application date, May* 30, 1923. *No.* 220,996.)

W. F. Bubb describes in British Patent No. 220,996, a form of interrupter or tunable buzzer illustrated by the accompanying diagram. Across the yoke Y of an electro-magnet a thin blade B is fixed by means of two screws S. This blade carries a contact strip L, which extends for about half the length of the blade. A vertical angle member T carries an adjustable screw N, fitted

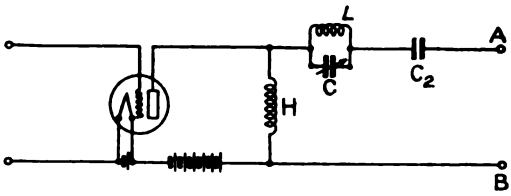


with a contact point P, which can be arranged to touch the strip L on the blade B. The vertical member T is provided with a horizontal slot in which the contact screw and its associated locking nuts and knobs can move. By altering the position of the screw in the slot the frequency at which the reed or blade will vibrate can be altered within very wide limits. An instrument of this type should prove very useful for laboratory measurements and experiments.

AN INTERESTING RADIO-FREQUENCY AMPLIFIER.

(*Application date, October* 22, 1923. *No.* 222,331.)

A very interesting radio-frequency amplifier is described in British Patent No. 222,331, granted to the Western Electric Co., Ltd., and G. H. Nash. The scheme is intended for radio-frequency

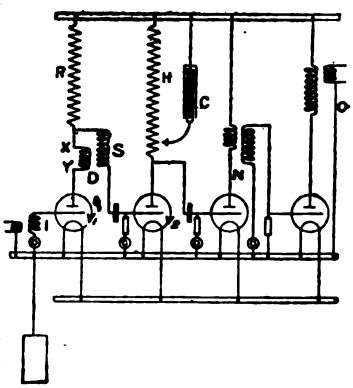


amplification on the broadcast band of wave-lengths. The anode circuit of the first valve contains a radio-frequency choke coil H, which has approximately an inductance of one henry. The output from this valve is shown as A and B, and these leads go respectively to the grid and filament circuit of the next valve. The grid lead, however, contains a tuned circuit LC, and a capacity C2. It is stated that for the present broadcasting range of 300 to 400 metres the coil L should have an inductance of 300 microhenries, while the capacity of the condenser should be 0·000 2 microfarads. The value of the fixed condenser C_2 is given as 0·000 1 microfarads. The object of the invention is to provide very great selectivity and to enable various broadcasting stations to be tuned in without mutual interference. The manner in which the arrangement operates should be obvious. There are really two tuned circuits. The first circuit is constituted by LC—C2, which is really a series acceptor circuit for the desired wave-length. The other circuit is simply LC and constitutes a rejector circuit for other wave-lengths, allowing only a very small potential to be applied to the grid of the next valve by undesired signals. The specification states that it is found possible to receive distant broadcasting stations in London while the London station is in operation. The choke H, of course, provides for the H.T. supply to the anode.

A DIFFERENTIATING AMPLIFIER.

(*Appointed date, June* 28, 1923. *No.* 222,413.)

A. F. Sykes describes in the above patent an amplifying system which is shown in the accompanying illustration and will be seen to consist of an amplifier containing both resistance and transformer coupled valves. The object of the invention is to provide an amplifying system which will differentiate between various frequencies so that almost any desired resulting characteristic can be obtained. The scheme is intended, of course, for speech frequencies, and the



amplifier is suitable for use with the well-known Sykes magnetophone or loud-speaker. The first valve is rendered operative by means of an ordinary input transformer I. The anode circuit of this valve contains a resistance R and the primary winding X Y of the first differentiating transformer D. The secondary S of this transformer is connected to the grid of the next valve by means of a condenser, and the winding is so adapted as to enable it to be connected either to the point X or the point Y of the primary winding. According to the direction in which it is wound it will either diminish or assist the combined effect of the resistance R and the inductance X Y. In the anode of the second valve there is a resistance H, which can be shunted at any point by a condenser C. The potentials derived from this valve are transferred to the next valve which also contains another differentiating transformer N. The general effect of the circuits associated with the valve V1, is to amplify uniformly for low frequencies, but to diminish or increase the values of the higher harmonics according to the connections of the transformers. The effect of the circuits associated with the second valve V2, is to amplify to a greater

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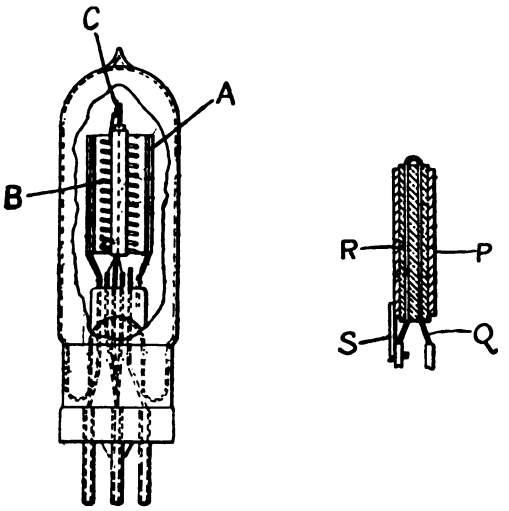
extent for the bass than for the treble. The claims of the invention seem to indicate that the amplifier is intended primarily for operating a loud-speaker. The idea of differentiating between frequencies is, of course, not new, but this particular method would seem to provide much subject matter for amateur experimental work.

CATHODE CONSTRUCTION.

(*Convention date, January* 8, 1923. *No.* 209,415.)

British Patent No. 209,415, granted to the Westinghouse Electric and Manufacturing Co., describes a type of equi-potential cathode shown in the accompanying diagram, which illustrates the actual construction of the cathode

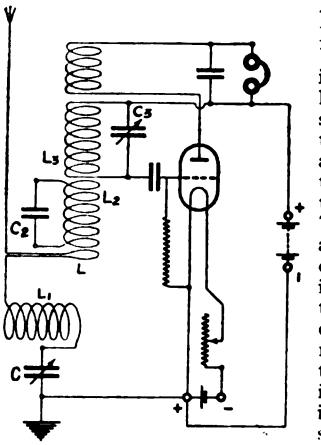


itself and also the method of incorporating it into a valve. It will be seen that it consists of a metal tube P, in the middle of which there is a heater wire Q. The space between the heater wire and the cylinder is filled with a material R, which is thermally conductive, but is at the same time electrically non-conductive. The second part of the diagram shows the electrode fixed into an ordinary valve, in which A is the anode, B the grid, and C the cathode. Electrical connection is made to the cathode surface by means of a link S, joined to one side of the heater wire. The claims of the invention are rather interesting and appear to be exceedingly broad. The essence of the invention lies in the use of some substance such as zircon between the heater filament and the cathode itself.

A PECULIAR RECEIVING CIRCUIT.

(*Application date, September* 18, 1923. *No.* 221,951.)

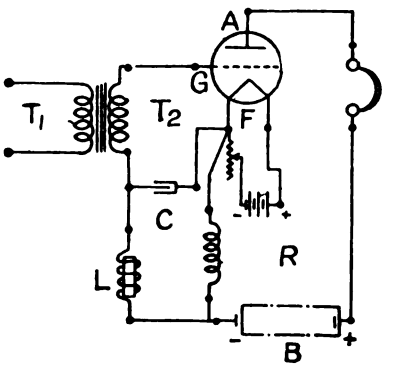
Cooke and Whitfield Wireless, Limited, claim in British Patent No. 221,951, a peculiar receiving arrangement which it is stated gives improved results over the circuits normally employed. Referring to the diagram it will be seen that the aerial circuit L L_1 C comprises two inductances and a capacity all connected in series. The first inductance L, consists of only one turn and this is tightly coupled to a tuned circuit L_2 C_2. This in turn is coupled to the grid circuit L_3 C_3 of the valve V. The grid circuit it will be observed happens to be shown connected to the grid condenser and the positive terminal of the high tension battery. The latter feature alone is, of course, quite old. Reaction is obtained between the grid and anode circuits in the normal manner. From the data provided in the specification it is rather hard to see why the arrangement gives ". . . the maximum clarity and tone," as it is stated to do in the first paragraph. The circuit reminds us of the Cockaday Four-Circuit Tuner.



A GRID BIAS SCHEME.

(*Application date, May* 25, 1923. *No.* 220,727.)

The accompanying illustration shows a grid biasing scheme which is described in British Patent No. 220,727, by E. A. Graham and W. J. Rickets. The object of the invention is to obviate the necessity of a grid bias battery by making use of the fall of potential along a resistance inserted in the anode circuit. This, of course, is not new, but the particular feature of the invention constitutes a modification of the method. Referring to the illustration, it will be seen that the anode circuit of the valve amplifier is completed through a non-inductive resistance R. The secondary winding of the transformer T1 T2, is connected to



the filament through a condenser C. The peculiar feature lies in the use of a choke L, which is connected across the resistance and the condenser. The arrangement is also claimed for an aerial or radio-frequency circuit, the one illustrated being intended, of course, for low frequency work.

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EXPERIMENTAL WIRELESS
& The WIRELESS ENGINEER

VOL. II. MARCH, 1925. No. 18.

Editorial Views.

The Radio Society of Great Britain.

WE have pleasure in informing our readers that commencing with this issue E.W. & W.E. will become the Official Organ of the Radio Society of Great Britain, a position which up to the present has been held by our weekly Sister Journal, *The Wireless World.*

The Radio Society of Great Britain, as most of our readers will be aware, is the headquarters in this country of amateur wireless technical exposition and discussion, and it seems fitting therefore that this Society should have as its organ the premier technical wireless journal of the country.

Developments which have taken place in *The Wireless World* under its new proprietorship have perhaps rendered that journal less fitted to undertake this work, for while the proceedings of the Society in question cannot but be of interest to every reader of a technical paper such as E.W. & W.E., the same can hardly now be said of *The Wireless World,* which under its new proprietorship has now broadened its circle of readers as to embrace a very large number, who, while interested in wireless as a means of entertainment, have not yet made such a technical hobby of it as to be deeply interested in the proceedings of the Society.

E.W. & W.E. is essentially a technical paper, and we feel sure all our readers will benefit by the publication of a full report, not only of the papers which are read before the members of the Radio Society, but also of the discussions at meetings. These full reports will appear first in the pages of E.W. & W.E., and we feel sure that our readers will look forward with pleasure to their publication.

Elementary Articles.

In an incautious moment last month we wrote in " Editorial Views " that we should like the opinions of readers as to whether they desired (*a*) an elementary series on circuit calculations, (*b*) one on setting up a wireless " lab."

We have suffered from excessive correspondence as a result, and the one salient fact that emerges is that half our correspondents want (*a*) and half want (*b*), and that each group beg us not to waste space on the other subject !

Incidentally, quite a large number lament that " much of the material in E.W. & W.E. is above our heads." I must thank these correspondents for the high compliment they pay us, in refraining from any suggestion that we should lower the general quality of our contents : they beg, on the other hand, for a series which will help them to raise their own knowledge to the required level.

But is it really a fact that the highly-technical articles which we often publish are beyond ordinary comprehension ? Remember that as a rule the author of such an article is trying to prove a point to his fellow " high-brows," and it is for this reason that

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he puts down in full his mathematical reasoning. In nearly every case the non-mathematical reader, *if he is content to take the author's correctness for granted*, can skip the proofs, and devote his energy to studying the conclusions reached and what they mean.

Just as an instance, take the recent extremely valuable article on L.F. Transformers, by Mr. D. W. Dye. This contained much mathematics which, though not advanced, was complicated. But the final conclusions reached (E.W. & W.E., Nov., 1924, pp. 80-83) are expressed in the simplest of language.

It seems appropriate to restate here the main lines of our policy, which have not changed since our acquisition of E.W. & W.E. We try to cater for the three following classes of reader (their order here is not necessarily their order of importance in our eyes) :—

(*a*) The professional wireless engineer, research student, and laboratory worker ;

(*b*) The advanced amateur experimenters especially those interested in transmission;

(*c*) Those who have taken up wireless, without much previous scientific training, but are really anxious to get some real knowledge of it.

It has been our endeavour, and we believe a successful endeavour, to provide in every issue some matter for each of the above classes of reader. But we have not space to repeat what is already known to all : to those who have written to us that they have to think very hard over our simplest articles we would reply that it was with that object we inserted them !

Now as to practical matters. We are satisfied that there is a call for both the series we suggested, and we have had some requests for a third series, on Mathematics for Wireless. The latter, we fear, must wait for a while. For many purposes, simple algebra and trigonometry are all that is needed, and we could not devote space to this. The other main necessity is an acquaintance with Calculus—by no means so difficult as supposed. This is admirably catered for already by such books as Perry's *Calculus for Engineers*, which can be studied with only the sketchiest previous mathematical knowledge, and should be on every wireless man's bookshelf. Special mathematical subjects needed in wireless, such as numerical computation, least squares, imaginaries, and so forth, will be dealt with from time to time.

The other two series we will tackle as soon as possible. But we must beg the indulgence of our readers, for these articles are difficult to write if they are to be easy to read. The writer must be absolutely at ease and abreast of his subject, and must have a special talent for explanation if he is to combine the scientific spirit with simple presentation.

Lastly, although, as stated above, we can hardly at present run a series on mathematics, we are convinced that a *real* knowledge of wireless cannot be got by those who are afraid to face and deal with figures, x's, and y's. Elaborate mathematics can often be dodged or taken for granted : but calculations such as those in " An Easy Way to Calculate Circuits (E.W &. W.E., Nov., 1924, p. 69) will always be cropping up, and there is no real excuse for shirking them.

Simple algebra, simple trigonometry, and the use of logs or slide-rule are all of them easy to learn if not already known, and in our view real progress in any branch of engineering is impossible without them.

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The Problem of Rectification. [R149

Below we give a short non-technical abstract of the important article on this subject which commences in this issue.

On p. 330 of this issue we commence the publication of a very important article by Mr. F. M. Colebrook, B.Sc., D.I.C., A.C.G.I., on Rectification. This subject is, undoubtedly, one of the most difficult of the many branches of wireless work which have hitherto lacked a detailed and thorough investigation.

Unfortunately the very nature of the subject precludes a complete treatment on very simple lines; and although Mr. Colebrook's article does not contain any highly advanced mathematics, it may yet be found fairly heavy by many of our readers; also it is fairly long. We therefore propose to give as shortly as possible, a non-technical abstract which will (as far as possible) present the conclusions reached in a simple form.

Throughout the greater part of the article, Mr. Colebrook is dealing with crystal rectification, although at the end he adds some notes on heterodyne and supersonic working. The main subject of valve detection, however, is reserved to a future article already in preparation.

The author of the article begins by showing examples of the "static characteristics" of the galena and perikon crystals with which the paper deals. Perikon, it will be remembered, is the trade name of the well-known Zincite-Bornite or Zincite-Pyrites combination. Next, he discusses what he refers to as the "rectification characteristic" —otherwise known as the "dynamic characteristic." The first of these two curves is the one got by applying a known D.C. voltage to the crystal—first in one direction and then in the other—and measuring the resulting currents. The result is the familiar curve shown in Fig. 1, p. 330. The second could be got, in theory, by measurement and calculation from the first: it shows the relation between any applied H.F. voltage and the resulting D.C. current. Such a curve is marked O in Fig. 9, p. 336. It is a curious point that in actual fact there are distinct differences between a dynamic curve got by calculation from a static one, on the one hand, and a dynamic curve obtained direct. In other words there is a real difference in the behaviour of a crystal at high and low frequencies.

A curve which will appear in a later part of the paper shows a drop of about 20 per cent. in output between 300 and 2 000 metres, but an almost constant result from 2 000 to 9 000. At what frequency the important changes take place we are not told. The cause of the change is not yet known. Whether it is due to the capacity of the crystal, or whether it is due to some actual lag in the electronic changes at the contact is a nice point for the physicist.

An important point brought out is that, whenever there is—as is usual—a high-resistance load in series with the crystal, the passage of the D.C. output current through this load causes a D.C. voltage which comes across the crystal itself. Unfortunately this voltage is always in such a direction as to hinder rather than help rectification, which indicates that a potentiometer will be of assistance for *any* crystal, though only necessary with some. It will be of even greater use for telephony, where we have a steady carrier wave, large compared with the modulation. There is a chance here for some experimenter to try measuring the output of the same crystal with and without potentiometer.

An important point next dealt with is that the apparent input resistance of the crystal, which governs the sharpness of tuning, increases with the resistance of the phones or other load, even if these are by-passed, as usual, by a condenser. This condenser, it should be noted, is of considerable assistance in getting large output.

The next point brought out—and a most important one—is the behaviour of the crystal from the point of view of its output circuit. Here the author of the article handles the theoretical side very ingeniously, getting the final result that the crystal in operation should behave as a generator—D.C. for a pure carrier wave, audio-frequency for a modulated wave—having a definite internal resistance. The voltage apparently generated varies directly with the input H.F. voltage, as one would expect, but also varies somewhat with the load. The apparent internal resistance also varies with

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load and input. The values obtained are given in detail in Section 6 of the article, but we give some rough idea here. The apparent internal resistance of Perikon is likely to vary from 1 000 ohms for weak input (·1 volt of H.F.) to 400 for strong signals (1·0 volt). Corresponding values for galena are 500 to 100 ohms. The apparent output E.M.F. is likely to be about ·5 the input for both.

Mr. Colebrook next takes up the question of efficiency, especially in regard to the best resistance for the load. At the outset, one is confronted with the question of defining just what "efficiency" is to mean. If the crystal is being used in the usual way, we want power in the output. If now the input power is constant, our "efficiency" will be the ratio of output to input power. If, however, the input *voltage* is constant, however much power we take from the circuit, then we want simply maximum power output. It has been said that we may regard the input power as constant in the case of an ordinary crystal receiver, the voltage across the aerial inductance dropping as the current taken increases. If, however, we have an H.F. valve with reaction, the input volts may be maintained constant even if the current increases. However, we have some information in our possession which inclines us to believe that under some circumstances the aerial may take more power from the ether as required, so that the voltage is maintained even without reaction.

The point is quite important, for the best load resistance is quite different in the two cases.

It is shown, both in theory and practice, that the maximum output power is got with a comparatively low resistance load, especially for large input. It would appear that in such cases phones of much lower resistance would be an advantage. But where the input power is constant instead of the voltage, a load of much higher resistance, more like the usual, is best.

In calculating the efficiency, it became necessary to work out the H.F. resistance of the crystal. As it happens, we ourselves have been doing some actual measurements on this point, and it is pleasing to note that the results agree well. The apparent H.F. resistance is a very variable factor, even with one crystal contact, depending on both the input volts and the output load. It can be as low as 100 ohms for no load and as high as 10 000 ohms with a high-resistance D.C. output load, with 1 volt of input, the values being larger for smaller input voltages.

It is interesting to note the actual output power and efficiency under various conditions. With the best load for maximum power, and 1 volt input, a galena took about ·002 watt and gave ·001; with ·5 volt input it took ·00025 watt and gave ·00012; with ·1 volt it took 5 microwatts and gave ·09; and with ·05 volt it took ·1 microwatt and gave ·004.

These figures do not, however, show the best efficiencies: the load was adjusted for maximum output power. With a much higher load, the efficiencies are, at large inputs, of the order of 90 per cent.; at small inputs say 2 or 3 per cent. This falling off emphasises a point which has long been our own belief: that the proper place for a crystal is in a valve set, where, by H.F. amplification, we can make it work at high efficiency. Further, as will be explained later, a crystal may be practically distortionless at high input, and is, in fact, the nearest thing to a distortionless rectifier. These, however, are the present writer's personal opinions. We will leave them and return to the article itself.

The author of the article discusses the use of the crystal as a "potential" rectifier, *i.e.*, used direct in the grid circuit of a valve, and shows that it may be very efficient. He points out, however, that the coupling from crystal to valve may be safely done by a transformer, as there is much less chance of distortion from a transformer in this position than in one between two valves.

Hitherto the author has been dealing entirely with the rectification of C.W. into D.C.—the simplest case. We have not laid stress on the point, because the investigation of modulated input, which he next undertakes, leads to results of essentially similar nature. The first point which he makes is that, where we are working with sufficient input to work on a more or less straight part of the "rectification characteristic," the modulation does not appreciably interfere with the straightforward rectification of the carrier wave. The important point here, from the non-technical point of view, is that hitherto most theoretical workers who have investigated rectification have assumed a

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"parabolic" characteristic—one that always gets steeper and steeper. This must result in distortion if used for telephony. But it has not generally been realised that within a quite useful working range the usual crystal does *not* have this sort of curve. After the first bend at the bottom it is often practically straight for a considerable range, and will then give distortionless rectification. It is only for weak signals that we have distortion.

Mr. Colebrook shows from his mathematical investigation that for modulated input just as for steady C.W., the detector has, from the output point of view, an apparent internal resistance and "generates" an apparent voltage—andio-frequency this time instead of D.C. as before.

The author's own summary of conclusions on the crystal detector, which will appear in a later instalment, is so clear and simple that we will not abstract it here. We will, however, go on to note one or two of the other points investigated.

Experiments were made with various metals as the contact wire, and resulted in the conclusion that there was no important difference. Varied pressure of contact also made little difference to the efficiency, though it caused great changes in the detector resistance, which needed changes in the circuit constants to maintain the same efficiency. Thus for a definite given circuit A.T.I. and telephones, there will be a best contact pressure.

The mathematical analysis developed for the above investigation is also used to investigate heterodyne and supersonic reception. The great sensitivity of beat reception is accounted for, and (an important point) it is shown that, under proper conditions, the change of frequency in the supersonic is, like crystal detection, distortionless.

Insulating Materials for H.F.

WE have known for some time, and have advised our readers privately, that many insulating materials, excellent for ordinary purposes, are by no means satisfactory in connection with H.F. circuits on account of dielectric losses.

Hitherto we have had no accurate experimental results to give our readers, but some are now available.

In an article in the December issue of the "Proceedings of the Institute of Radio Engineers" of America—would we had such an institute here!—Mr. R. V. Guthrie, jun., gives the results of some tests at the State University of Iowa; and in an article in *QST* for February, Messrs. Preston and Hall, of the Bureau of Standards, give some further figures. The tests were all carried out at radio-frequencies.

We have expressed the results as power factors. The power losses involved in using these insulators instead of air will be proportional to these power factors, and we give in the following table the actual power factors: the proportional losses in terms of ebonite as 1 can be got by multiplying these by 100. Our table is abridged, for in some cases the authors tested several samples of the same material, in which cases we give the average:—

Material.	Power Factor.	
	Guthrie.	Preston and Hall.
Asbestos and binders ..	—	>*
Bakelite	·046	—
Celeron	·057	—
Celluloid	·042	·03
Ebonite	·010	—
Fibre	·059	·04
Fibroc	·041	—
Formica	·050	—
Glass	·008	·008
,, (pyrex)	—	·006
Leatheroid	·048	—
Marble	—	>*
Mica	·000 4	·000 7
,, built up with binder	—	·016
Paper, waxed	—	·02
Petrite	>*	—
Radion	·017	—
Slate	—	>*
Sulphur	·006	—
Varnish	—	·003—·005
Vulcabeston	·044	—
Waxes:		
Beeswax	—	·015
Ceresin	—	·000 3
Condenser compound	—	·005
Paraffin	—	·000 16
Wood, dry..	·05	·03—·1
,, baked and then boiled in wax ..	—	·015—·03

*> Indicates that the losses are so large as to make the material undesirable for wireless work.

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We add a few notes on these insulators, from our own experience :—

ASBESTOS.—It seems quite likely that asbestos itself may be quite efficient; but, as in the case of mica, its losses are greatly increased when it is worked up with binding materials.

BAKELITE.—A good material mechanically. Much superior to ebonite for power work at low frequencies and used to a very large extent on American sets.

CELERON.—Exact composition not known, but believed to be more or less like formica.

CELLULOID.—A very tempting material, being so easy to work by softening in hot water. But a snare for H.F. work. Remember that celluloid varnish, so often advised for coils, etc., is just as bad. No figures are given for shellac, but it is believed to be much superior.

EBONITE.—We all know it. Bad mechanically, being brittle and yet inclined to warp; also it spoils by exposure to light and air. None the less, the only panel and former material for efficiency in H.F. circuits.

FIBRE.—High losses. Also suffers the defect of absorbing moisture. The latter trouble may be minimised by boiling in wax.

FIBROC.—Not known.

FORMICA.—One of the laminated series, composed of thin layers of various materials (usually cellulose, *i.e.* paper, etc.) bound by a synthetic resin. Good mechanically, and superior to ebonite *except* for H.F. work.

GLASS.—Both the experimenters got good results; probably their samples were a special glass made for insulation. Ordinary glass often has very high losses.

LEATHEROID.—Not known, but very probably allied to pegamoid, which is canvas with celluloid varnish.

MARBLE.—Comment is needless. Luckily it is not a favourite panel material for wireless sets!

MICA.—This shows up splendidly—unfortunately mica panels are hardly practicable. But beware of built-up mica products, which often have a power factor of ·05 or more.

PAPER.—This is very variable. Special paper with first-class wax is often used in condensers, but losses must always be faced, and for radio-frequency circuits it should not be used.

PETRITE.—Nothing known of this.

RADION.—This is a type of ebonite, and gives results very similar.

SLATE.—See note on marble.

SULPHUR.—A much neglected material. Has magnificent insulating properties. Can often be used very well for bushings, being easily melted and cast in position.

VARNISH.—This is not shellac, which is usually used for insulation, but high-class varnish for wood.

VULCABESTON.—Believed to be a rubber-asbestos product.

WAXES.—*Beeswax*, of course, is not greatly used; in any case it is not a satisfactory material.

Ceresin is, we believe, a special variety of paraffin wax, though we are not certain.

Compound condenser wax is usually an adulterated paraffin.

Paraffin wax shows up as one of the outstanding good insulators. Contrary to the usual belief it is often better practice to use wax (sparingly, of course) than shellac for coils and the like.

WOOD.—This shows high losses, but we have reason to believe that some samples of well-dried timber are much better. We know that many high-power transmitting stations use it in preference to anything else.

ERRATA.

We regret that two printer's errors crept into Mr. Banner's article on "Increasing the Range of D.C. Measuring Instruments" in our last issue.

The formula at the bottom of p. 294, given as

$$R_s=\left(\frac{A_1}{A_2-A_2}\right)R_1$$

should read

$$R_s=\left(\frac{A_1}{A_2-A_1}\right)R_1$$

and the dimensions of the shunt given on line 9 of first column of p. 295 as 1 cm. × 5 mm., should be 1 cm. × 0·5 mm.

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The Arrangement of Wireless Books and Information.

Part VI: R600 and R700. [025·4

This series draws to a close: these are the last purely wireless sections, and the next instalment will be the concluding one

Before proceeding to the classes R600 and R700, we should like to call our readers' attention to a slip in our last issue. Under R510 we stated that ship traffic would be dealt with under R531. This should have been R530: further, we omitted a new heading which we had prepared for the purpose, and we should therefore be glad if readers will insert, after R537, the four following headings :—

*R538	Ordinary Commercial Services.
* ·1	Work on board ship.
* ·3	Coastal work.
* ·5	Long-range " fixed station " service.

R600 Station Equipment, Management, and Operation.

In this section, as in the next, we have been obliged to strike out a new line to a considerable extent, for, as will be seen on examining the tables, the B.S. extension has not gone very deeply into them.

As usual, the numbers between R600 and R610 are for general matters, arranged according to the "form division"; but one should beware of including therein items which should more properly be placed under R610 or later.

R610 Descriptions of stations and their equipment.

R611 Long-wave stations.
R612 Extra-short-wave stations.

In the B.S. extension, there followed here two numbers :—

R613 Ship stations.
R614 D.F. stations.

But this seems hardly sufficient for classifying a series of station descriptions, so we propose that the two above numbers be not used; a place will be found for such items in the suggested extension below.

*R615 Station descriptions, classified by systems of working.

These items are classified in exact correspondence with R400 "Systems of Working," the figure 4 being omitted and the remaining figures placed after R615. We therefore only give a skeleton list: fuller details can be found under R400.

*R615·1	Modulated-wave stations.
* ·11	Spark.
* ·12	Telephony.
* ·2	C.W. stations.
* ·23	Valve stations.
* ·35	Stations for secret work.
* ·4	Remote control stations.
* ·45	Relay stations.
* ·46	Duplex and multiplex stations.
* ·47	" Wired Wireless " stations.
* ·48	Recording and high-speed stations.

*** These subdivisions are proposed by us as a tentative further extension.**

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*R616 Station descriptions classified according to use or purpose.

Here again we take advantage of a previous extension; this section is divided according to R500 "Applications and Uses of Wireless." As in the case of R615, we only give a skeleton; further details can be filled in from R500, by dropping the "5," and placing the figures which follow it after R616.

*R616·1 Stations for assisting navigation.
* ·2 Aircraft stations.
* ·3 Commercial stations generally.
* ·4 Private stations.
* ·45 Amateur stations.
* ·5 Broadcasting stations (in the wide sense).
* ·57 "Entertainment" Broadcasting stations.
* ·6 War service stations.
* ·9 Stations classified simply by location.

R620 Operation and management.

In the B.S. extension, the whole subdivision of this section is carried out by means of the "Form Division," the class numbers extending only from R620·01 to R620·09. This is, of course, an entirely legitimate method which is always open. But we feel that further division is called for in this case. Now upon seeing the endings ·001, etc., the inquirer will probably look straight to the "form division" list, which is not so closely sub-divided as would be useful.

We therefore do not repeat the B.S. extension here, as it will be found in Part I. of this series: we have divided the class R620 on the same lines, but in a manner which leaves the way open for further extension.

*R621 Construction and installation.
*R621·1 Choice of site.
* ·2 Design and Construction of buildings.
* ·3 Erection of masts, installation of aerial and earth or counterpoise.
* ·4 Installation of apparatus.

*R622 Regulation and control.
*R622·1 Special wireless laws and regulations.
* ·2 Other statutory regulations (Factory and Workshop Acts).
* ·3 Licences.
* ·4 Official inspections

*R623 Operation.
*R623·1 Personnel.
* ·11 Engineering staff.
* ·111 Training.
* ·112 Qualifications.
* ·113 Conditions of service.
* ·12 Operating staff (Sub-divide as above.)
* ·2 Routine of traffic.
* ·21 Official regulations and forms.
* ·22 Local and special traffic methods.
* ·23 Logs and records.

*R624 Testing and maintenance.
*R624·1 Routine tests.
* ·11 Tests for radiation.
* ·12 Tests for wave-length.
* ·13 Tests for modulation or keying.
* ·2 Maintenance and running repair: workshops, etc.

*R625 Administration.
*R625·1 General management, staff personnel
* ·2 Accounts.
* ·21 Costs, supply of materials, etc.
* ·26 Revenue: charges, inter-station accounts, etc.

*** These subdivisions are proposed by us as a tentative further extension.**

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R700 The Manufacture and Sale of Wireless Apparatus.

Here we have actually a modification of the "form division." The class ·01 is essentially a general one, and in Dewey's original scheme it was specially extended for engineering, to take account of the most general things in all engineering work: Materials and their Properties. We borrow some items direct: many other items under R700 are also from Dewey.

R701		Wireless materials: tests and properties.
	R701·1	General properties.
	* ·12	Testing.
	* ·2	Timber.
	* ·7	Iron and steel.
	* ·8	Other Metals.
	* ·9	Other Materials.

R710 Factories.

Again we are provided for in the original Dewey. We could class such matter under "Non-wireless" in R800, giving the simple Dewey numbers, but it seems best to find room here for as much as we want.

	R710·05	(Form Division) works administration, etc., is especially useful here.
R711		Drawing office.
	*R711·1	General.
	* ·2	Arrangement.
	* ·3	Equipment and tools.
	* ·4	Supplies and stores.
	* ·5	Methods and processes.
R712		Wood-working shops. Divide as R711.
*R713		Smithy.
*R714		Foundry.
*R715		Machine shops.
*R719		Assembly and finishing.

All to be divided as R711 above.

R730 Office Organisation.

*R731	Buildings, &c.
*R732	Equipment.
*R733	Personnel.
*R734	Administration and management.
*R735	Files and records.
*R737	Correspondence.

R740	Sales Organisation.	Both divided as R730 above.
*R750	Publicity Organisation.	

At this point our special extension, as such, comes to an end, for R900 is not classified. But we propose to give, in our next issue, some extracts from the main Dewey tables, to assist in the classification of items on non-wireless subjects, which as already explained, are grouped under R800.

*** These subdivisions are proposed by us as a tentative further extension.**

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The Rectifying Detector.

By F. M. Colebrook, B.Sc., D.I.C., A.C.G.I.

Part I. [R149

An exhaustive investigation, theoretical and experimental, into one of the most difficult problems of the Wireless Engineer.

IN the early days of wireless telegraphy the subject of rectification, or, as it was more usually termed, detection, was one of very great practical importance, and received a correspondingly large amount of attention. The advent of the two-electrode and, later, the three-electrode valve, however, greatly reduced the difficulties attendant on this part of the radio-telegraphic process and, at the same time, opened up a wide field of unexplored ground, with the result that attention was transferred to other branches of wireless technique.

More recently still, the popularisation of wireless telegraphy and telephony and the revival of crystal reception have given a renewed interest to the subject of rectification. It still remains however in a comparatively elementary state. Very little work of an exact character has been published on the subject, and the basis of its technique is still largely empirical. The chief reasons for this are probably the difficulty of the measurements involved (particularly at the high radio frequencies used in broadcasting) and the apparent intractability of the mathematical side of the subject.

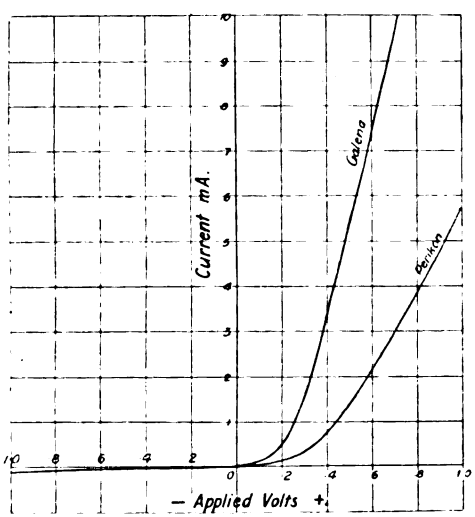

Fig. 1. *The characteristics of two typical rectifying crystals.*

The writer has recently been engaged on some work which required a fairly detailed understanding of the process of rectification, and has taken the opportunity to carry out a fairly extensive investigation of this matter. Since the results obtained are likely to be of general interest, they are embodied in as compact a manner as possible in the following paper.

The treatment of the subject will be divided approximately as follows :—

1. The Description of a Rectifying Conductor.
   Determination and analysis of the static characteristic.
   (*a*) Small amplitudes.
   (*b*) Large amplitudes.
2. The Rectification Effect.
3. Some Particular Cases.
   (*a*) Parabolic characteristic.
   (*b*) Exponential characteristic.
   (*c*) Perfect rectifier.
   (*d*) Practical case.
4. Loaded Rectifier Circuit.
   Determination of rectification characteristic.
   Analysis of rectification characteristic.
   (*a*) Large amplitudes.
      i. General.
      ii. Apparent internal resistance (no load).
      iii. Apparent rectified E.M.F. (no load).

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(b) Small amplitudes.

5. Continuous Wave Rectification Efficiency.
   Experimental results on C.W. efficiency.
6. Potential Rectification (Infinite load).
   Experimental results on potential rectification.
7. The Rectification of a Modulated E.M.F.
8. The Effect of a Modulation Load.
9. Efficiency in the Rectification of a Modulated E.M.F.
   Experimental results with modulation loads.
   The choice of telephones.
10. Distortion in the Rectification of Modulated Currents.
11. The Influence of Contact Conditions.
    (a) Galena.
    (b) Perikon.
12. The Variation of the Sensitivity with Wave-length.
13. Summary of Results with simple Crystal Rectifiers.
14. Crystal-Valve Combinations.
15. Heterodyne Reception.
16. The Supersonic Heterodyne.

In order to illustrate and confirm the principles deduced from the general theoretical considerations, a large number of measurements were carried out with representative specimens of the two crystal detectors in most general use, namely, galena and perikon.

1. The Description of a Rectifying Conductor.

For any ordinary non-inductive conductor the relation between the instantaneous value of the current and that of the E.M.F. which produces it is given by

$$i=ae, \quad .. \quad .. \quad (1\cdot1)$$

where i and e are the instantaneous values of voltage and current. The coefficient a is known as the conductance of the conductor, its reciprocal being known as the resistance.

The distinctive property of a rectifying conductor is that the relation between i and e is of a less simple character, the relation being expressible in the general case by

$$i=f(e) \quad .. \quad .. \quad (1\cdot2)$$

i.e., the current, instead of being a simple multiple of the E.M.F. is some other finite, and in all practical cases continuous, function of the E.M.F.

Assuming the function to be capable of expansion in positive integral powers of e, we have

$$i=a_0+a_1e+a_2e^2+ \ . \ . \ . \ +a_ne^n + \ . \ . \ . \ . \ (1\cdot3)$$

This functional relationship, under specified conditions of time variation of the

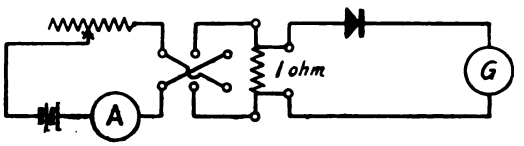

Fig. 2. *Circuit for obtaining curves such as those in Figs. 1 and 3.*

E.M.F., is termed the characteristic of the rectifier under the given conditions. Examples of such conductors are :—

(a) The grid or anode circuits of a thermionic valve ;
(b) Various arrangements of inorganic crystalline substances, i.e., "crystal detectors" ;
(c) Certain electrolytic conductors, etc., etc.

The curves shown in Fig. 1 may be taken as representative of rectifying characteristics. They are, in fact, the static or continuous current characteristics of two crystal detectors.

In all cases, except certain valve circuits, the coefficient a_0 in equation (1·3) is zero. In all that follows it will be assumed to be zero unless otherwise stated.

Determination and Analysis of the Static Characteristic.

The measurement of the continuous current or static characteristics of the various detectors examined was made by means of the circuit illustrated in Fig. 2. The arrangement is a convenient one for applying accurately known voltages to the terminals of the detector. It was found that in every case the current required an appreciable time, about a minute or so, to become steady in value, there being generally a positive "creep" in the pass direction, and a negative in the reverse direction. Typical results are shown in Fig. 1.

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It was found that in every case the static characteristics would admit of fairly simple description over the regions (*a*) applied voltage less than 100 millivolts, and (*b*) applied voltage greater than 0·3 to 0·5 volts. For convenience these regions will be referred to as corresponding with small signal amplitudes and large signal amplitudes respectively.

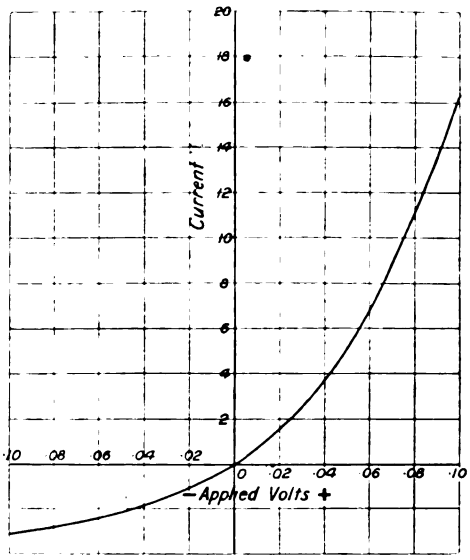

Fig. 3. *A characteristic for very small input, the current is in microamps.*

(*a*) *Small amplitudes.*

A suitable enlargement of the region ± 100 millivolts gives a curve such as that shown in Fig. 3, which actually refers to one of the perikon detectors examined. In general an equation

$$i_e = a_1 e + a_2 e^2 + a_3 e^3 + a_4 e^4$$

can be made to fit such a curve fairly closely. A simple method of determining the coefficients is worthy of note. For an E.M.F. e we shall have the equation given above. For an equal E.M.F. of opposite sign the current will be

$$i_{-e} = -a_1 e + a_2 e^2 - a_3 e^3 + a_4 e^4$$

Therefore

$$\frac{i_e + i_{-e}}{2e^2} = a_2 + a_4 e^2$$

and

$$\frac{i_e - i_{-e}}{2e} = a_1 + a_3 e^2.$$

Thus a_2 and a_4 can be found by dividing the algebraic sum of i_e and i_{-e} by $2e^2$ and plotting the result against e^2, which will give an approximately straight line. The coefficients a_1 and a_3 can be found in a similar manner by plotting the algebraic difference of i_e and i_{-e} divided by $2e$ against e^2.

(*b*) *Large amplitudes.*

It was found that for applied voltages greater than about ·3 to ·5 volts the characteristics approximated very closely to a straight line of the form

$$i = a_1(e - e_0) \text{ (See Fig. 4).}$$

The constants a_1 and e_0 can obviously be measured directly from the actual curve.

2. The Rectification Effect.

If the E.M.F. e be a pure sine wave alternation represented by

$$e = E \sin \omega t \quad .. \quad .. \quad (2\cdot1)$$

the current i will in general be an alternating one of the same periodicity as e, but of some irregular wave form. By Fourier's theorem, therefore,

$$i = f(e) = f(E \sin \omega t) \quad .. \quad (2\cdot2)$$

$$= i_0 + i_1 + i_2 + \ldots + i_n + \ldots \quad (2\cdot3)$$

i_0 being a continuous current and i_n being a current of sine wave form and of frequency $\frac{n\omega}{2\pi}$. By the same theorem the amplitudes of these various currents will be given by

$$i_1 = \frac{1}{T}\int_0^T f(e).dt \quad .. \quad (2\cdot4)$$

$$I_1 = \frac{2}{T}\int_0^T f(e) \sin \omega t.dt \quad .. \quad (2\cdot5)$$

and in general

$$I_n = \frac{2}{T}\int_0^T f(e) \sin n\omega t.dt \quad .. \quad (2\cdot6)$$

where

$$\omega = \frac{2\pi}{T} \quad .. \quad .. \quad (2\cdot7)$$

(It is here assumed that the series 2·3 will contain no cosine terms, these will exist among the higher terms, but not in the fundamental with which we are concerned.)

We see from the above that the application of an alternating E.M.F. to a conductor

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of the type under consideration will produce a continuous current represented by

$$i_0=\frac{1}{T}\int_0^T f(e).dt \quad .. \quad (2\cdot8)$$

together with an alternating current of the fundamental frequency and, in general, a whole series of harmonics. The first of these, which will hereafter be termed the "rectified current," is, of course, the objective in the practical applications of rectifiers in wireless telegraphy and telephony.

If, as in equation 1·3

$$i=a_1E\sin\omega t+a_2E^2\sin^2\omega t+\ldots +a_nE^n\sin^n\omega t+\ldots \quad .. \quad (2\cdot9)$$

plus cosine terms,

then general expressions can be found for i_0, i_1, etc., in terms of the coefficients a_1, a_2, etc., by the application of the integrals

$$\frac{1}{T}\int_0^T \sin^{2p}\omega t.dt=\frac{1\cdot3\cdot5\ldots(2p-1)}{2.4.6\ldots(2p)} \quad (2\cdot10)$$

$$\frac{1}{T}\int_0^T \sin^{(2p+1)}\omega t.dt=0 \quad .. \quad .. \quad (2\cdot11)$$

from which it can easily be shown that

$$i_0=\frac{1}{2}a_2E^2+\frac{1\cdot3}{2\cdot4}a_4E^4+\frac{1\cdot3\cdot5}{2.4.6}a_6E^6+\ldots \quad (2\cdot12)$$

and

$$I_1=2\left[\frac{1}{2}a_1E+\frac{1\cdot3}{2.4}a_3E^3+\frac{1\cdot3\cdot5}{2.4.6}a_5E^5+\ldots\right] \quad .. \quad (2\cdot13)$$

where I_1 is the amplitude of i_1.

Similar expressions could be found for the other harmonics, but they are not of any practical importance.

It is of interest to note at this point that of the various alternating components of the total current only that of the fundamental frequency will be associated with the consumption of any energy from the source of the E.M.F., since, for all values of n, except $n=1$, the mean value of ei_n over a period is zero. Other points to note are that the expression for i_0 contains only the coefficients of even powers of e, while the expression for I_1 contains the coefficients of the odd powers of e; also that for very small values of e the expressions will approximate to the simple forms :—

$$i_0=\frac{1}{2}a_2E^2 \quad .. \quad .. \quad .. \quad (2\cdot14)$$

$$I_1=a_1E \quad .. \quad .. \quad .. \quad (2\cdot15)$$

3. Some Particular Cases.

It will be as well to illustrate the form taken by the above general expressions in certain particular cases of some practical importance.

(*a*) *Parabolic characteristic.*

If

$$i=a_1e+a_2e^2 \quad .. \quad .. \quad (3\cdot1)$$

then

$$i_0=\frac{1}{2}a_2E^2 \quad .. \quad .. \quad (3\cdot2)$$

and

$$I_1=a_1E \quad .. \quad .. \quad (3\cdot3)$$

while for $n>2$

$$I_n=0 \quad .. \quad .. \quad (3\cdot4)$$

(*b*) *Exponential characteristic.*

If

$$i=a\varepsilon^{be} \quad .. \quad .. \quad (3\cdot5)$$

and

$$e=e_0+E\sin\omega t \quad .. \quad (3\cdot6)$$

then

$$i_0=a\varepsilon^{be_0}\left[1+\left(\frac{bE}{2}\right)^2+\frac{1}{2!}\left(\frac{bE}{2}\right)^4+\frac{1}{3!}\left(\frac{bE}{2}\right)^6+\ldots\right] \quad .. \quad (3\cdot7)$$

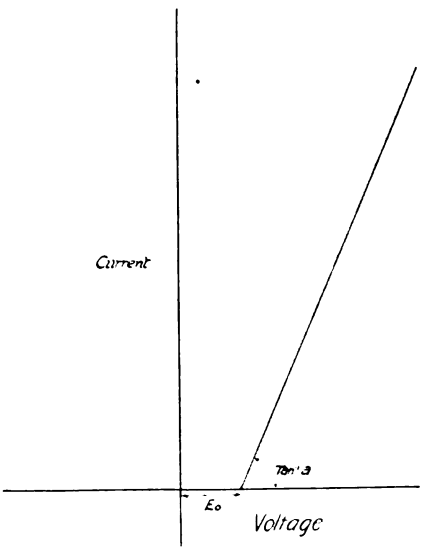

Fig. 4. *At large amplitudes, the crystal characteristic approximates to a straight line.*

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and

$$I_1 = 2a\varepsilon^{be}\left[\frac{bE}{2} + \frac{2}{2!}\left(\frac{bE}{2}\right)^3 + \right.$$
$$\left. + \frac{3}{3!}\left(\frac{bE}{2}\right)^5 + \ldots\right] \quad .. \quad (3{\cdot}8)$$

This will be found to have a very important practical application.

(*c*) *Perfect rectifier.*

An interesting special case is that of the theoretically perfect rectifier specified by

$$i = a_1 e \text{ for positive values of } e \quad (3{\cdot}9)$$
$$= 0 \text{ for negative values of } e \quad (3{\cdot}10)$$

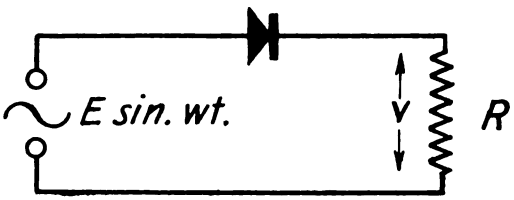

Fig. 5. *The simplest output load.*

For this case

$$i_0 = \frac{1}{T}\int_0^{\frac{T}{2}} a_1 E \sin \omega t.dt = a_1 \frac{E}{\pi} \quad .. \quad (3{\cdot}11)$$

and

$$I_1 = \frac{2}{T}\int_0^{\frac{T}{2}} a_1 E \sin^2 \omega t.dt \quad .. \quad .. \quad (3{\cdot}12)$$

$$= a_1 \frac{E}{2} \quad .. \quad .. \quad .. \quad (3{\cdot}13)$$

(*d*) *Practical case.*

A case similar to the above, but of greater practical interest, since it will be found to be related to crystal reception, is that illustrated in Fig. 4 :—

$$i = a_1 (e - e_0) \text{ for } e > e_0 \quad .. \quad (3{\cdot}14)$$
$$= 0 \quad \text{for } e < e_0 \quad .. \quad (3{\cdot}15)$$

Putting

$$e_0 = E \sin \omega t_1 \quad .. \quad .. \quad (3{\cdot}16)$$

then

$$i_0 = \frac{1}{T}\int_{t_1}^{(\frac{t}{2}-t_1)} a_1(e - e_0).dt \quad .. \quad .. \quad (3{\cdot}17)$$

$$= \frac{a_1 E}{\pi}\left[\sqrt{1 - \frac{e_0^2}{E^2}} - \frac{e_0}{E}\left(\frac{\pi}{2} - \arcsin\frac{e_0}{E}\right)\right] \quad (3{\cdot}18)$$

which, for small values of e_0/E approximates to

$$i_0 = \frac{a_1 E}{\pi} - \frac{a_1 e_0}{2} \quad .. \quad .. \quad (3{\cdot}19)$$

Similarly

$$I_1 = \frac{a_1 E}{}\left[\left(\frac{\pi}{2} - \arcsin\frac{e_0}{E}\right) - \frac{e_0}{E}\sqrt{1 - \frac{e_0^2}{E^2}}\right] \quad (3{\cdot}20)$$

which for small values of e_0/E approximates to

$$I_1 = \frac{a_1 E}{2} - \frac{a_1 e_0}{\pi} \quad .. \quad .. \quad (3{\cdot}21)$$

4. Loaded Rectifier Circuit.

In the practical applications of rectification there will invariably be some form of load in the detector circuit, in which the energy represented by the rectified component of the current is converted into heat or mechanical energy. To make the above analysis applicable to practical conditions, therefore, it will be necessary to consider how the equations will be modified by the presence of a load in series with the rectifier. The first arrangement to be considered will be that illustrated in Fig. 5.

The currents represented by i, flowing in the load, will give rise to a back E.M.F. v which will, in general, consist of a continuous component and an infinite series of high-frequency harmonics, *i.e.*,

$$v = v_0 + v_1 + v_2 + \ldots + v_n + \ldots\ldots \quad (4{\cdot}1)$$

The E.M.F. acting across the detector will now be $(e - v)$, so that equation 1·2 becomes

$$i = f(e - v) \quad .. \quad .. \quad (4{\cdot}2)$$

A little consideration will make clear that in the general case the mathematical analysis of the effect of a load in the detector circuit will be impossibly complex. It would, moreover, be of very little value, since in all practical cases steps are taken to ensure that all the components of v except v_0 are made negligibly small. This result is obtained by connecting across the load a condenser of sufficiently large magnitude to provide a path of low impedance for the high-frequency components of the current. The arrangement will then be as shown in Fig. 6, and we have

$$v = v_0, \quad .. \quad .. \quad (4{\cdot}3)$$

so that

$$i = f(e - v_0) \quad .. \quad .. \quad (4{\cdot}4)$$

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This is illustrated in Fig. 7. The effect of the load is seen to be a shifting back of the centre point of the oscillation by an amount v_0, the actual amplitude of the oscillation being unaffected.

If the load were not short-circuited by the condenser it is clear that in addition to the shifting back of the centre point of the oscillation there would also be a reduction in the amplitude of the oscillation on account of the high-frequency components of the back E.M.F., the net result being not only a greater reduction of i_0 than in the first case, but also a useless consumption of energy on account of the passage of the high-frequency components of the current through the load.

The above diagram also makes clear another important feature of rectification of the type under consideration, i.e., that for any given amplitude of e, the current of the fundamental frequency (which

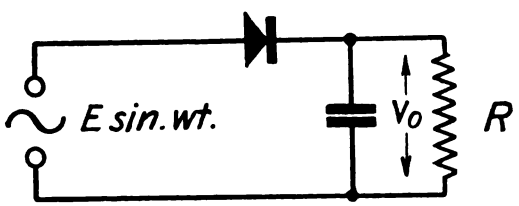

Fig. 6. *As a rule the output load has a condenser to by-pass the high-frequency components.*

determines the effective high-frequency resistance of the detector) will depend very considerably on v_0, i.e., on the magnitude of the D.C. load. In general the effective high-frequency resistance of the detector will increase with the load. Further reference will be made to this point later.

In all that follows it will be assumed that the back E.M.F. due to the load can be represented by the single term v_0, so that equation (4·4) applies. Expanding this equation by Taylor's theorem, we have

$$i=f(e)-v_0f'(e)+\frac{v_0^2}{2!}f''(e)-\ldots$$

$$\ldots+(-1)^n\frac{v_0^n}{n!}f^n(e)+\ldots \quad (4\cdot5)$$

where

$$f^n(e)=\frac{d^n}{de^n}f(e) \quad .. \quad (4\cdot6)$$

The rectified current i_0 will then be given by

$$i_0=\frac{1}{T}\int_0^T f(e).dt-v_0\frac{1}{T}\int_0^T f'(e).dt+\ldots$$

$$\ldots+\frac{v_0^2}{2!}\frac{1}{T}\int_0^T f''(e).dt-\ldots$$

$$\ldots+(-1)^n\frac{v_0^n}{n!}\frac{1}{T}\int_0^T f^n(e).dt+\ldots \quad (4\cdot7)$$

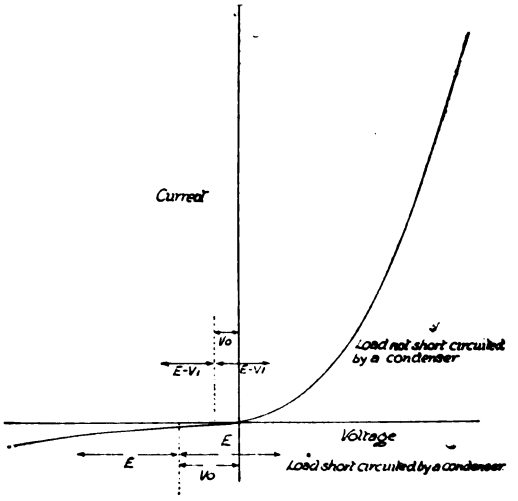

Fig. 7. *Illustrating the effect of the load in diminishing the output.*

The first term is the value of i_0 corresponding to zero load. Its value in terms of the characteristic has already been determined. For abbreviation we will put

$$\frac{1}{T}\int_0^T f(e)dt=F(E) \quad .. \quad (4\cdot8)$$

Similarly, putting

$$\frac{1}{T}\int_0^T f'(e)dt=F_1(E), \text{ etc.} \quad (4\cdot9)$$

equation 4·8 becomes

$$i_0=F(E)-v_0F_1(E)+\frac{v_0^2}{2!}F_2(E)-\ldots$$

$$\ldots+(-1)^n\frac{v_0^n}{n!}F_n(E)+\ldots \quad (4\cdot10)$$

$$=F(E)-Ri_0F_1(E)+\frac{R^2i_0^2}{2!}F_2(E)-$$

$$\ldots+(-1)^n\frac{R^ni_0^n}{n!}F_n(E)+\ldots \quad (4\cdot11)$$

R being the D.C. resistance of the load.

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The general expressions for $F(E)$, $F_1(E)$, etc., in terms of the characteristic of the detector could easily be obtained in precisely the same manner as for $F(E)$. The expressions will not, however, be of much practical value. It is clear that whereas $F(E)$, $F_2(E)$, etc., will contain only the even coefficients a_2, a_4, etc., $F_1(E)$, $F_3(E)$, etc., will contain only the odd coefficients a_1, a_3, a_5, etc.

The expression for I_1, the amplitude of the fundamental high-frequency component, can be obtained in an exactly similar manner. Putting, for abbreviation,

$$\frac{2}{T}\int_0^T f(e)\sin\omega t.dt=\phi(E) \qquad (4\cdot12)$$

and

$$\frac{2}{T}\int_0^T f'(e)\sin\omega t.dt=\phi_1(E) \qquad (4\cdot13)$$

etc., etc.

then I_1 is given by

$$I_1=\phi(E)-v_0\phi_1(E)+\frac{v_0^2}{2!}\phi_2(E)-$$

$$\ldots+(-1)^n\frac{v_0^n}{n!}\phi_n(E)-\ldots \qquad (4\cdot14)$$

Theoretically, equation 4·11 is capable of solution for i_0. It will be seen, however, that if n terms on the right hand side are significant, the determination of i_0 will involve the solution of an $(n-1)$th power equation, which would be a very difficult

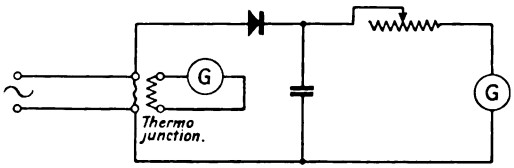

Fig. 8. *The circuit used for measuring the "Rectification Characteristic" (D.C. output compared with H.F. input).*

matter. It will be of interest to point out the general features of the solution in the case where only the first two terms of the series are significant. This will apply when R is very small or when $F_2(E)$, etc., are very small. Fortunately the two most generally used crystal detectors conform approximately to this latter requirement for relatively large amplitudes of e. Equation 4·11 now becomes

$$i_0=F(E)-Ri_0F_1(E) \quad .. \quad (4\cdot15)$$

giving

$$i_0=\frac{F(E)}{1+RF_1(E)}=\frac{F(E)/F_1(E)}{1/F_1(E)+R} \qquad (4\cdot16)$$

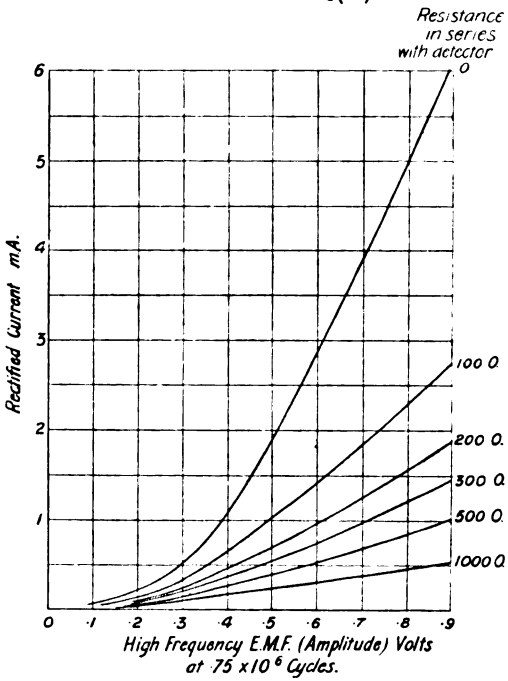

Fig. 9. *Rectification characteristics for Galena with various loads.*

Under these conditions it appears that the internal resistance of the crystal or detector to the rectified current is $1/F_1(E)$, the rectified E.M.F. producing the current being $F(E)/F_1(E)$. If the load is zero, the current will be the rectified E.M.F. divided by the internal resistance, i.e.,

$$i_0=\frac{F(E)/F_1(E)}{1/F_1(E)}=F(E) \qquad (4\cdot17)$$

as already shown.

Even in the general case, where $F_2(E)$, etc., are not negligibly small, the above equation (4·16) will be true for a small value of R, and it will therefore be true to say that $1/F_1(E)$ and $F(E)/F_1(E)$ are respectively the internal resistance and the rectified E.M.F. at "no load."

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The next approximation to equation (4·16), taking account of v_0^2, but neglecting higher powers, will be

$$i_0 = \frac{\dfrac{F(E)}{F_1(E)} + \dfrac{v_0^2}{2}\,\dfrac{F_2(E)}{F_1(E)}}{R + \dfrac{1}{F_1(E)}} \quad \ldots \quad \ldots \quad (4{\cdot}18)$$

This is equivalent to an increase of the rectified E.M.F. by an amount $\frac{v_0^2}{2} \cdot \frac{F_2(E)}{F_1(E)}$, a term dependent on R. Thus as the load increases the rectified E.M.F. will also appear to increase slightly. It is probable, therefore, that if R is increased to infinity the

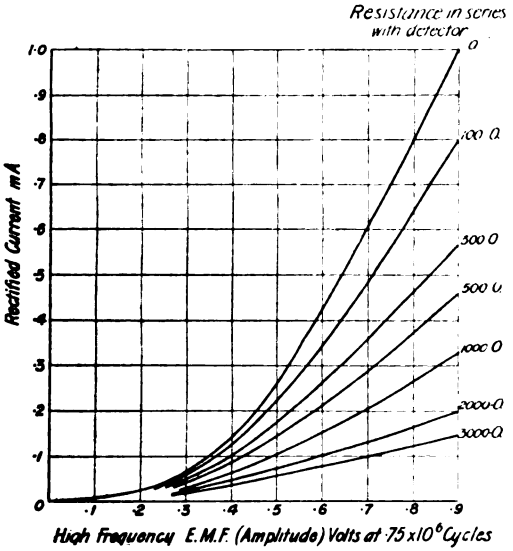

Fig. 10. *Rectification characteristics for Perikon with various loads.*

ultimate value of v_0 will be greater than the value of the rectified E.M.F. determined by the change of current due to a small load R. These conclusions are illustrated by the experimental results described further on.

The above discussion may be summarised as follows: Under all conditions of signal amplitude and load the rectified current can be expressed in the form

$$i_0 = \frac{E_c}{R_c + R} \quad \ldots \quad \ldots \quad \ldots \quad (4{\cdot}19)$$

where E_c is an apparent rectified E.M.F., and R_c an apparent internal resistance. In general R_c will depend on the amplitude of the signal E.M.F. Both E_c and R_c may vary to some extent with the load resistance R. In the limit, when $R = \infty$,

$$v_0 = Ri_0 = \frac{RE_c}{R_c + R} = E_c \quad \ldots \quad (4{\cdot}20)$$

but, as already explained, the value of E_c in equation (4·20) will probably be somewhat greater than its value in equation (4·19).

The quantities E_c and R_c are clearly the important practical characteristics of a detector. The means of determining these quantities will now be described.

Determination of Rectification Characteristic.

The above term is used to designate the curve obtained by plotting the continuous component of the rectified current against the signal amplitude, with no load in series with the detector. The circuit used for this purpose is shown in Fig. 8. The first series of measurements was made at a frequency corresponding to a wave-length of 400 metres. To avoid uncertainty in the measurement of the signal E.M.F., the

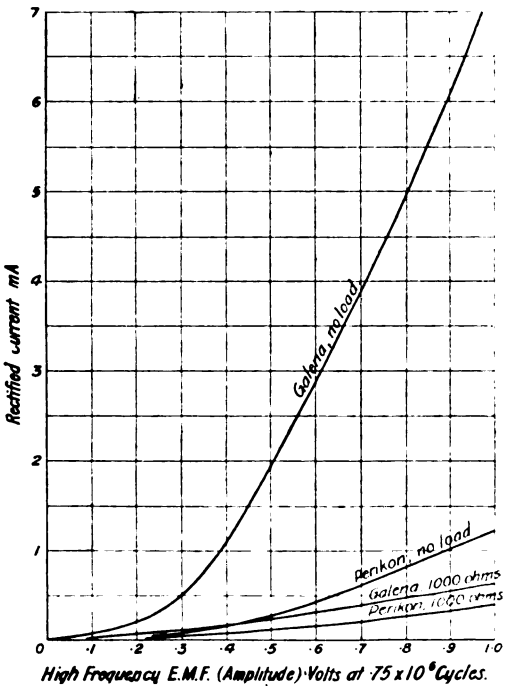

Fig. 11. *Curves from Figs. 9 and 10 to the same scale, for comparison.*

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heater of a non-contact type of thermo-junction ammeter was used as the source

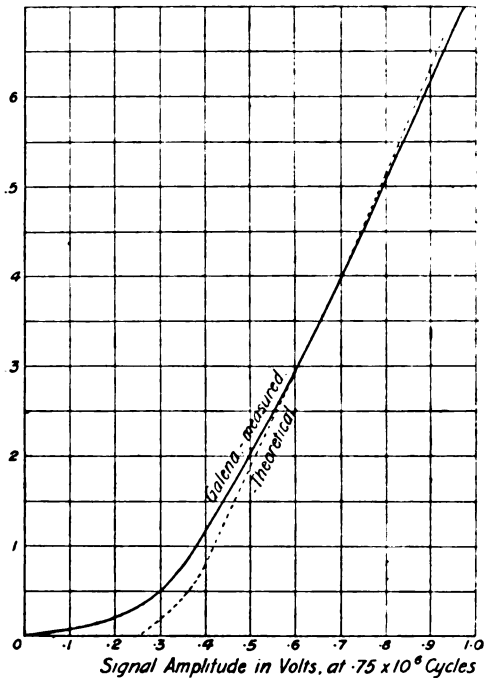

Fig. 12. *The measured curve for large amplitudes approximates to that calculated on the basis of a simple straight-line law for* i *and* e.

of potential. Proper precautions were taken to ensure that the whole of the high-frequency E.M.F. acting in the detector circuit was that derived from the fall of potential in the heater resistance.

Typical results are illustrated in Figs. 9 and 10, which also show the curves obtained with various D.C. loads. One distinction between the two detectors is clear from these curves, and is further emphasised in the comparative lines in Fig. 11. At no load, galena appears to be much more sensitive than perikon. This apparent superiority is very greatly diminished with a fairly high load in series, showing that it is mainly due, not to a higher rectified E.M.F., but to a lower apparent internal resistance.

Analysis of Rectification Characteristic.

(*a*) *Large amplitudes.*

(i) *General.*—It has been stated that for large amplitudes the static characteristics would approximate to

$$i = a_1 (e - e_0) \text{ for } e > e_0$$
$$= 0 \quad \text{for } e < e_0$$

This is confirmed in Fig. 12, which shows the actual performance of a galena detector compared with that deduced from a characteristic of the above type. (See para. 3.) It is found that the constants a_1 and e_0 deduced from the rectification characteristic are different from those given by the static characteristic. The following table gives the comparison for two typical specimens :—

	Galena.		Perikon.	
	Static.	Dynamic.	Static.	Dynamic.
a_1	$2{\cdot}13 \times 10^{-2}$	$3{\cdot}53 \times 10^{-2}$	$\cdot 96 \times 10^{-2}$	$\cdot 56 \times 10^{-2}$
e_0	·25	·25	·4	·22

It will be seen that the deviation of the dynamic from the static characteristic is in opposite directions for the above two specimens.

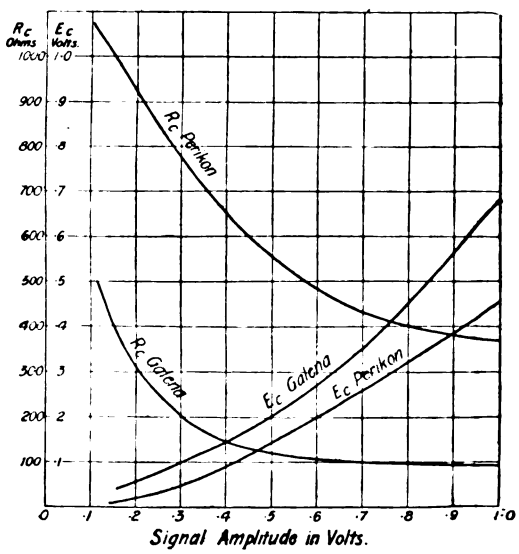

Fig. 13. *Variation of* E_c *and* R_c *(apparent E.M.F. and internal resistance) for varying input voltage (large input).*

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(ii) *Apparent internal resistance at no-load.*—It has been shown above that the apparent internal resistance of a rectifier at zero load could be determined by inserting a small resistance (short-circuited by a condenser) in series with the rectifier and measuring the consequent change in the rectified current. If i_0 be the current corresponding to no load, and i_0' the current corresponding to a load R, then (equation 4·19)

$$i_0 = \frac{E_c}{R_c} \text{ and } i'_0 = \frac{E_c}{R_c+R}$$

therefore

$$R_c = \frac{Ri'_0}{i_0 - i'_0}$$

The variation of R_c with E was determined in this manner for the two specimen detectors described above. The results are shown in the curves of Fig. 13.

It should be noted that in each case the value of R_c approaches $\frac{2}{a_1}$ at its lower limit. (See equation 3·19.) The value of R_c determined as above applies only to zero load: with increasing load it will in general increase, but for large amplitudes the change of R_c will not be very great, and the zero load value can certainly be taken as approximately the value of the load which will give the maximum D.C. power with a constant potential input.

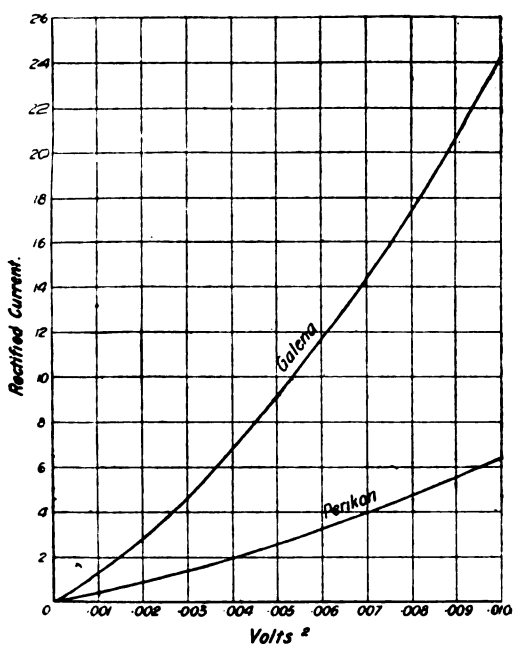

Fig. 14. *D.C. output against square of H.F. input, for small inputs.*

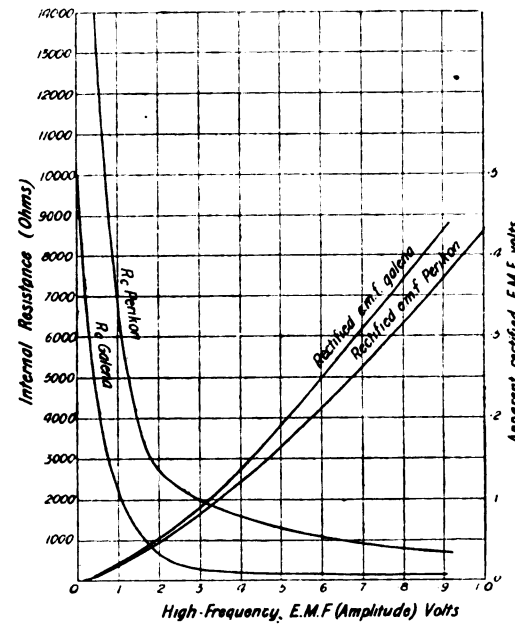

Fig. 15. *Combined curves showing R_c and E_c for both large and small inputs.*

(iii) *Apparent rectified E.M.F. at no load.*—Since, at no load,

$$i_0 = \frac{E_c}{R_c}; \text{ it is obvious that } E_c = R_c i_0$$

The variation of E_c with E is shown in Fig. 13. It will be seen that as far as E_c is concerned, there is far less difference between the two detectors than the no-load sensitivity would appear to indicate.

(*b*) *Small amplitudes.*

Fig. 14 shows the no-load characteristics for the representative specimens of galena and perikon plotted against the square of the r.m.s. value of the high-frequency E.M.F. Expressing the lines in the form

$$i_0 = \frac{1}{2}a_2E^2 + \frac{3}{8}a_4E^4 = a_2E_s^2 + \frac{3}{2}a_4E_s^4,$$

(where E_s=r.m.s. volts)

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we see that the values of a_2 and a_4 can be obtained by plotting i_0/E_s^2 against E_s^2, since

$$\frac{i_0}{E_s^2} = a_2 + \frac{3}{2}a_4E_s^2$$

The no-load values of R_c and E_c can be determined as already described. Since (equations 4·15 and 4·19)

$$\frac{1}{R_c} = F_1(E) = a_1 + \frac{3}{2}a_3E^2$$

a_1 and a_3 can be determined by plotting $1/R_c$ against E^2. The following table gives the comparison between the static and dynamic characteristics of the two specimens examined :—

	Perikon.		Galena.	
	Static.	Dynamic.	Static.	Dynamic.
a_1	$6{\cdot}4 \times 10^{-5}$	$5{\cdot}0 \times 10^{-5}$	$8{\cdot}75 \times 10^{-5}$	$8{\cdot}5 \times 10^{-5}$
a_2	$5{\cdot}3 \times 10^{-4}$	$4{\cdot}0 \times 10^{-4}$	$9{\cdot}5 \times 10^{-4}$	13×10^{-4}
a_3	$2{\cdot}8 \times 10^{-3}$	$2{\cdot}2 \times 10^{-3}$	$1{\cdot}05 \times 10^{-2}$	$1{\cdot}5 \times 10^{-2}$
a_4	$2{\cdot}4 \times 10^{-2}$	$1{\cdot}6 \times 10^{-2}$	$5{\cdot}5 \times 10^{-2}$	$7{\cdot}5 \times 10^{-2}$

For the sake of completeness the values of E_c and R_c were determined both for large and small amplitudes for the contact points having the above characteristics. The curves of Fig. 15 show the results obtained.

(To be continued.)

Principles and Methods of Obtaining High-Tension Supply from Direct Current Mains.

By L. C. Grant (2QP). **[R355**

How to run transmitters cheaply from the public supply.

THIS short article is intended to give the broad principles which must be observed if the direct current mains are to be used as a source of supply for feeding valve oscillators, and as most small transmitting valves operate on a maximum anode potential of 500-600 volts, it will be found that observance of the following remarks will enable most small power transmitters to be successfully operated from the public supply, at a purely nominal cost for energy. In passing, it may be useful to mention that to get the most out of a transmitter valve, does not by any means mean piling on anode voltage, but rather to pay a little more attention to the high frequency circuits to reduce their impedance and to tune accurately and carefully all tuned circuits. The writer, in his own experience with both

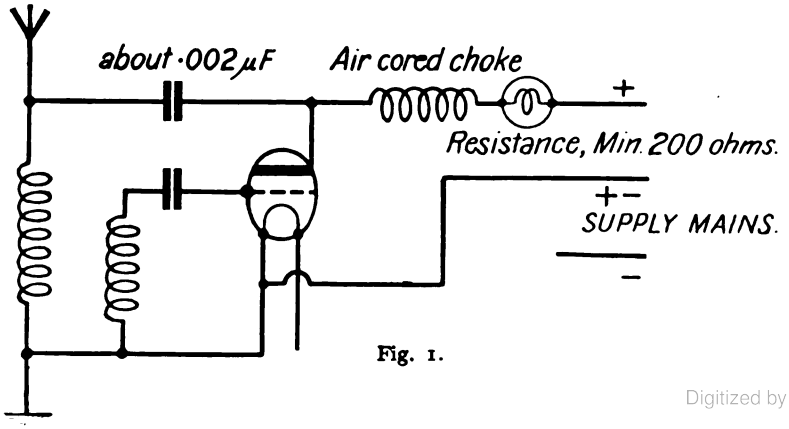

Fig. 1.

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large and small transmitters, has found that very often after tuning and adjusting a circuit, the addition of further anode voltage either has no effect on the output, or may even reduce it, in both instances causing additional heating of the anodes.

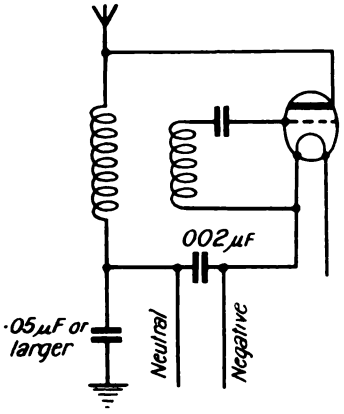

Fig. 2.

For small transmitters, the possibility of using the lighting mains for the anode supply is particularly attractive. The difficulties of application sometimes seem formidable, and even after coupling up, the valves may be found to be very stubborn, but usually this will be found to be due to an incorrect potential distribution of one of the circuits, probably imposed through the necessity of respecting an earthed supply main or similar trouble. In theory, these difficulties can be overcome by ringing the changes on the relative electrical positions of transmitter and supply mains in such a way that points of equipotential are always connected together, either directly or through some suitable coupling of minute impedance. Troubles such as these are usually accentuated when single circuit tuners are used, and as the efficiency of some versions of single circuit tuner is usually 10 per cent. to 30 per cent. higher than that of a magnetically coupled tuner, it is probable that the single circuit tuner will always be used quite extensively.

It is fundamentally a less difficult job to get a double or other magnetically coupled circuit to work, and they are, therefore, often cited as a cure for difficulties due to non-oscillating transmitting sets. Nevertheless, this should not be taken as an excuse for neglecting observance of correct conditions for connecting up the transmitter to the mains, or trouble with fluctuating output, varying wave-length, etc., will very often result.

The usual arrangement of a distribution network of any size, is a three wire supply with the neutral or middle wire connected to ground. This gives a potential difference from either positive or negative conductor to ground of 250 volts. It also introduces the risk of accidental short circuit in case of grounding of one of the "outers"—the positive and negative conductors. The possibility of setting up such a short circuit must be carefully guarded against and in the recommendations made in this article this will be attended to in such a way that there is no abnormal danger.

Supply Positive to Neutral.

A single-sided supply is almost universal when only a lighting supply is called for from the mains. With a positive service, and using a single circuit transmitter, this is the only service that can be used without any alteration to the transmitter connections. The connections are shown in Fig. 1. The stopping condenser and radio frequency choke (a 200-1 000 turn Igranic coil will do for the latter) are essentials, but they are equally necessary whatever the H.T. source. A lamp or other resistance of a minimum of 200 ohms should be connected in series with the positive or anode feed and will effectively remove the chance of a short circuit at the transmitter side of the supply. A 32 c.p. carbon lamp is as good as anything.* If a lamp is

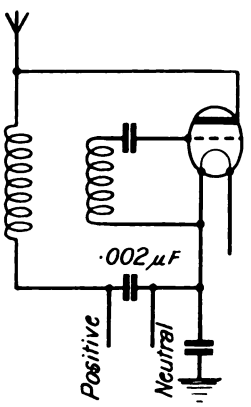

Fig. 3.

*[Personally, we should prefer a metal filament lamp. The lamp will have much less than its rated current through it, and the "cool" resistance of a tungsten filament is much less than when hot, while that of a carbon one is greater.—Ed., E.W. & W.E.]

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used as the resistance, it should be rated at the same voltage as the supply, otherwise a short circuit would destroy the lamp.

Supply from Neutral to Negative.

In this case the neutral or grounded conductor is at the highest potential, and if connected direct to the valve anode, will result in earthing of the anode. Fig. 2 shows the correct method of coupling up to a supply of this nature so that the potential balance or distribution remains correct. A fairly large condenser should be connected across the high tension terminals, as these are included in the high frequency circuit. It is also advisable to connect a condenser in series with the earth connection, thus avoiding metallic contact with earth. This earth lead condenser should be quite large, at least ·05μF, and even so large as ·5μF. If it is too small, the speech in telephony will be distorted. The diagram should be faithfully followed, as there are several possible "niggers." A lamp or other resistance can be used in the H.T. negative as an additional precaution. Compare this diagram with the diagram following, Fig. 3, which shows a method similar in principle for taking supply from the positive main. This method can be used instead of that shown in Fig. 1.

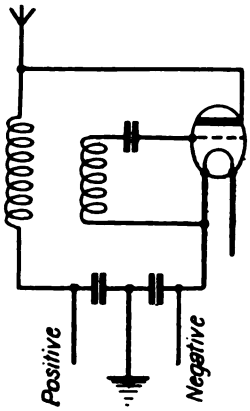

Fig. 4.

Supply Positive to Negative.

This implies the use of both "outers" of a three-wire network and will give about 500 volts for the anode supply. This voltage will work most 30-watt valves, and the writer has actually worked valves rated at 30 watts (dissipation at the anode), and put as much as 50 watts into the high frequency circuit. The circuit shown in Fig. 4 has been devised specially for working "large" small valves. The supply mains are bridged by two similar condensers connected in series. These condensers should be at least ·1μF, and larger values can be used with advantage. The middle connection between condensers is connected to ground and forms the wireless earth. This method provides quite a stable neutral and works well. It can be further stabilised if required by bridging each condenser with a fairly high resistance, say about 1 000 ohms each. A couple of small metal filament lamps will do quite well, but if energy consumption is a desideratum, these resistances can be as high as 100 000 ohms. A couple of anode resistances of a fairly robust type will answer fairly well.

In a future article the writer hopes to introduce some new methods of coupling up to A.C. mains and also to give details of a small static unit for supplying D.C. to a valve transmitter.

A New Method of Producing Ultra-Short Waves.

By J. Taylor, B.Sc. **[R411·0124**

A description of a successful experiment and the apparatus used.

Introduction.

A MOST interesting method has been put forward recently for the production of electro-magnetic waves of very short length. ("A New Source of Very Short Electro-magnetic Waves." *Zeitschrift fur Physik*, 24, B. 3 and 4, H., p. 153.)

Until recently, short electro-magnetic waves had always been produced by ordinary Hertzian oscillators, and this method, although very suitable for the longer wave-lengths of the short series, is only with considerable difficulty applicable to the production of the shorter wave-length radiation. This defect is due to several disabilities inherent to the method. There is the destructive action of the discharge on the oscillator itself, the falling off of the energy emission as the wave-length is decreased, and the fact that the wave-length

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does not decrease in proportion to the decrease of the length of the oscillator in the case of the smaller wave-lengths.

Notwithstanding these difficulties, Nichols and Tear extended the range of explored wave-lengths two octaves down the scale, and obtained wave-lengths as small as 1·8 mm. (*Phys. Rev.* 2, 21, p. 587, 1923.)

Method of Nichols and Tear.

The advance was effected by using extreme precautions in the construction of the oscillators, which consisted of tungsten cylinders (A and B of Fig. 1), 0·5 to 0·2 mm. in diameter, and of length from 5·0 to 0·2 mm., sealed into glass. The diagrams of Figs. 1 and 2 indicate the experimental arrangement used in these researches. The gap of the oscillator itself was immersed in paraffin, which was projected through it by means of a jet (J, Fig. 2). The auxiliary gaps (c and d, Fig. 2) were cooled by compressed air.

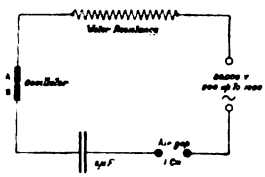

Fig. 1.

Experimental Arrangement for Nichols and Tear's method of producing short waves.

The short wave emission is, of course, given off by the system of the two tungsten cylinders alone, which constitute an oscillator of very small capacity and inductance.

Notwithstanding this decided advance, there still remained a very considerable gap between the shortest known wireless and electro-magnetic waves, and the longest known waves on the other side of the gap, of Rubens and Baeyer (1911).

The following method gives a wave-length range between some 40 mm. and the shortest wave-length yet observed, of 0·082 mm.

The Method.

A mixture of metal filings (in these experiments, brass or aluminium were used) and machine oil (M, Fig. 3), contained in a vessel, is maintained in constant motion by a churn (C, Fig. 3), so that the consistency of the mixture is uniform. A wheel or roller (R) is kept in rotation by a small motor, and thus the oil-filing mixture is raised and carried round on the periphery of the wheel. The leads of an induction coil (L_1 and L_2) are placed in the mixture on the wheel periphery, and discharge takes place through the top layer. As a consequence of the discharge, waves are given off from the oil-filing mixture, the frequency depending largely upon the dimensions of the filings.

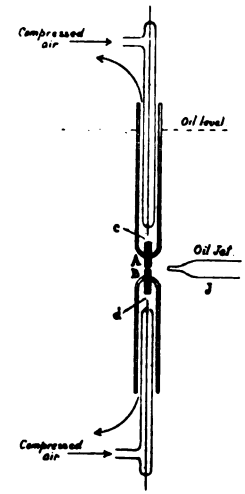

Fig. 2.

Diagram of Nichols and Tear's Oscillator.

The resemblance between the present method and that of Nichols and Tear is obvious. We may consider a pair of filings, between which sparking or a discharge occurs, as a small oscillator giving out its characteristic radiation. The exact length of the emitted wave will consequently depend to a great extent upon the magnitude and shape of the filings, and their distribution, which is maintained as constant as possible by the churning action of C. Further, since there are a large number of these small oscillators in action at any instant, the actual emission of short wave-length energy is much greater than in the previous method, where one oscillator only is in operation during the whole time.

The wave-length and energy distribution were measured by an interferometer method, and it was found in one particular case that

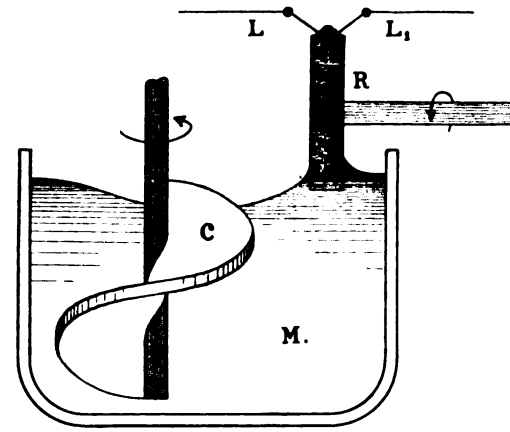

Fig. 3.

a wave-length as small as 0·082 mm. was obtained. The maximum energy distribution was in the region of greatest wave-lengths.

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The Perfect Set. [R132

Part VI: H.F. Amplification.

Unfortunately it seems likely that this subject, like the last one dealt with, will spread itself over several issues.

IN settling down to study H.F. amplification (of the usual type) we are faced with the disconcerting fact that nearly all the points so carefully dealt with in our previous articles on L.F. work now either cease to apply or (even worse) are exactly reversed.

The cause of this is a simple one. Of the two forms of distortion mentioned (see E.W. & W.E., January, 1925, p. 228) "wave-form" distortion is unimportant and "amplitude" distortion is *desirable*.

In fact, the problem is an essentially different one. Here we wish to amplify currents of one frequency, and not those of other frequencies (this statement needs modification in some cases). Again, we are amplifying simply for the purpose of rectification afterwards: we wish to preserve unchanged the *envelope* of the wave-form (the dot-dash line in Fig. 1), and to a first approximation at any rate, a change in the form of the H.F. current curve, say, from the sine-curve shown in full line to the peaked curve shown dotted, will not affect the form of the envelope. It may affect the L.F. amplitude, but that is another matter.

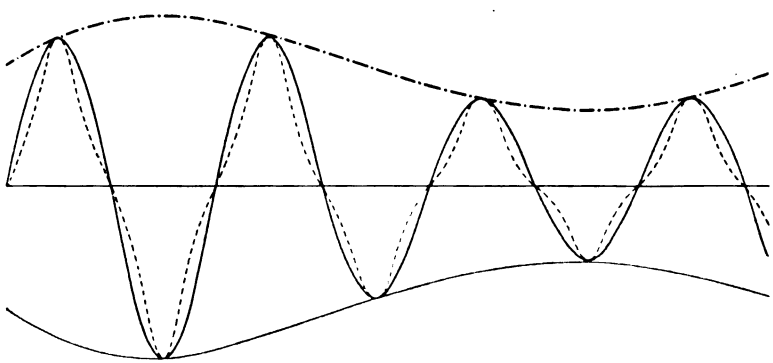

Fig. 1.

These facts give us a certain freedom in the design of an H.F. amplifier, but other matters crop up which limit us again. The most notable of these are oscillation, and low amplification at high frequencies. Both of these are to a certain extent tied up with the question of "effective input impedance," which we shall deal with in a very summary manner.

First, however, let us go back to Fig. 1, and study a little more closely the effect of wave-form distortion. If any part of our amplifier has a "non-linear response," this will be present. "Non-linear response" simply means an output not directly proportional to the input. To take the simplest possible example, suppose we are using a low anode voltage, so that our valve is being used at the lower part of its curve, as in Fig. 2. If the input is a pure sine-wave, the output will not be. It will contain a second harmonic.

Now what the valve is really doing is to convert a certain amount of D.C. power (from the anode battery) into H.F. alternating power of some given frequency controlled by the input. If any of the D.C. power is turned into, say, "300-metre" power instead of "600-metre," it is simply wasted, for the circuits tuned to 600, which follow in other stages, will not allow it to pass. So we are simply reducing the amplification.

Thus, although H.F. wave-form distortion does not necessarily matter as regards L.F. tone, it should be avoided in order to keep up the amplification. This can only be done by seeing that we work on proper voltage values, so that the straight part of the valve curve is used.

Now let us take up the question of instability—unwanted oscillation. There are two main causes of this, one simple, the

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other much misunderstood. The simple one is unintentional coupling. We usually provide intentional back-coupling, either by coils or capacity-coupling; but it is a

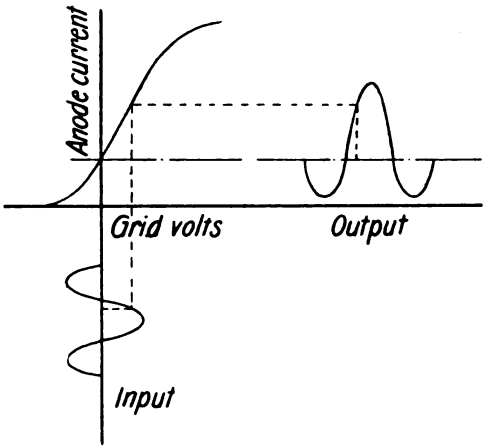

Fig. 2.

truism to state that every part of a set has some coupling, both magnetic and electric, with every other part in the same cabinet. If, owing to faulty design, these couplings are above a certain amount, and of a certain sense, there will be self-oscillation. The remedy is care in design and construction, with screening if necessary.

The other and much misunderstood factor is the effect of the internal capacity of the valve. This is usually held up as a bogey which may cause oscillation without rhyme or reason. As a matter of fact it is capable of quite definite examination, and as far as appears at present, can only cause oscillation under quite definite conditions, of which the most important is that, to have regeneration from this cause *there must be an inductive load in the plate circuit.*

Input Impedance.

Above, we mentioned, but did not define, the "effective input impedance." Suppose that, as in Fig. 3, we apply to a valve set

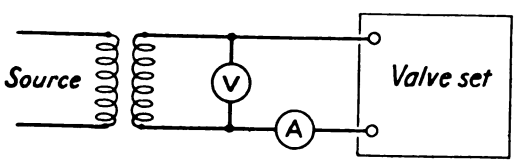

Fig. 3.

a measured voltage at any given frequency, and also measure the current input. Say, voltage E at frequency f ($\omega=2\pi f$), and current I. Then $\frac{E}{I}$ is the apparent input impedance. Now any impedance can be split up into a resistance R ohms and a reactance X ohms, and X may be either positive or negative. A *positive* reactance is that set up by a coil of inductance L henries, where

$$L=\frac{X}{\omega}$$

A *negative* reactance is that set up by a condenser of capacity C farads, where

$$C=-\frac{1}{\omega X}$$

As far as we know at present, the input reactance of a valve is always negative, *i.e.*, the valve behaves towards the input circuit like a small condenser (usually 10 to 50$\mu\mu$F) in series with a resistance. The value of the resistance is the crux of the matter.

Let us note, firstly, just what is meant by various values of this resistance;

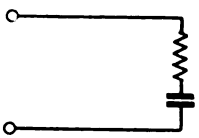

Fig. 4.

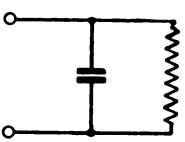

Fig. 5.

remember that it is considered as a resistance *in series with* the capacity load, as in Fig. 4. It is possible also to imagine any impedance as being split up into a resistance in parallel with a reactance, as in Fig. 5. A zero resistance in Fig. 4 gives the same result as an infinite resistance in Fig. 5—a pure capacity load absorbing no power. Generally, a low resistance in series is equivalent to a very high resistance in parallel.

Now there is a common tendency to believe that if the grid is negative, so that there is no D.C. grid current, and hence apparently an infinite parallel resistance in Fig. 5, then the valve acts as a pure capacity load. *This is totally mistaken.* There is quite definite experimental evidence and theore-

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tical proof that whenever there is a load in the plate circuit there is an apparent resistance in the grid circuit; and the value of this resistance depends on the load. We will not go deeply into this matter now, for we are at the moment actually engaged in a lengthy research into the actual numerical values of the resistance under various conditions. But there are certain qualitative results which are quite definite.

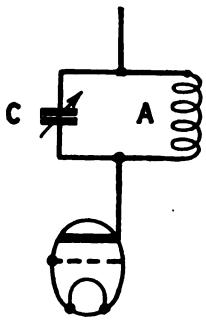

Fig. 6.

The input resistance decreases steadily as the reactance of the load increases. Thus, suppose the anode circuit is of the type shown in Fig. 6. If the condenser is too large for resonance, the whole of *A* behaves as a condenser; its reactance is negative (see above), and the input resistance is large. Reduce the condenser: the reactance becomes zero (*i.e.*, increases from its negative value), and the R_g (the input resistance) is smaller. Reduce the condenser still further: the whole of *A* begins to behave as an inductance; its reactance becomes positive and R_g becomes smaller still. At some particular value of *C* it will be zero, and the valve takes no power from the input circuit. Reduce *C* still further, and R_g becomes negative.

What does this mean? Here we are faced by the whole question of whether such a thing as "negative resistance" can have any meaning. But we cannot enter into it. For our purposes it simply means that whereas a positive value of R_g means that the valve is absorbing from the input a power of R_g multiplied by the square of the input current, a negative R_g means that it is *supplying* this power to the input circuit. It is, in fact, "Regenerating." Now the input circuit has its own resistance, and the first effect of negative R_g is to reduce the total resistance of the aerial input circuit. If, however, R_g becomes (while still negative in sign) greater in amount than the aerial and input circuit resistance, then the valve will not only overcome these losses, but will supply free power to the aerial: it is oscillating.

When is a "Tuned Anode" Untuned?

If the above statements are accepted, and they are based on reliable authority accepted by the leading wireless engineers, we arrive at one important point. The only case where the valve's internal capacity can set up oscillation is that in which there is an inductive load in the plate circuit. If in practice (as seems, alas! to be the case) oscillation is obtained with the favourite "tuned anode" circuit, it is because the anode circuit is *not* tuned. The user has decreased the capacity below resonance: he gets louder signals, but this is due to the reaction he has introduced by going out of tune. If he kept the capacity up to resonance (say 5 per cent. of its value above the apparent setting for loudest signals), and compensated for the loss of regeneration by moving up the reaction coil, he would get better signals.

To a certain extent this has been a digression, but input impedance is such an important matter, and has been so seldom dealt with, that we think we may be excused. The idea brought out in the last paragraph has to the best of our knowledge never been dealt with before in print.

Coupling Difficulties.

Now we come to another point: the effect of this comparatively low input impedance on the effective amplification of the previous valve. Take the circuit shown in Fig. 7, where Z_a is some kind of impedance in the anode circuit of the first valve—it may be a pure resistance, or a combined resistance and reactance. Note that the H.T. battery is shunted by a condenser. Consequently we can treat the anode circuit, *as regards alternating currents*, as simply an impedance between anode and filament. Also the grid circuit consists of the condenser C_1 the leak

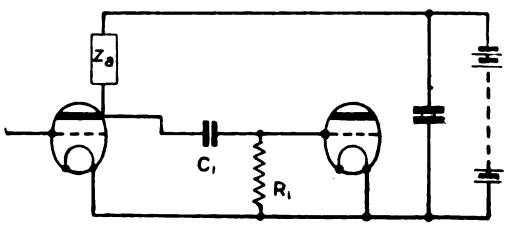

Fig. 7.

resistance R_1, and the condenser and resistance C_g and R_g making up the valve input

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impedance. It can easily be shown that with usual valves this whole assembly (C_1, R_1, C_g, R_g) forms an impedance not much different from Z_g itself. So that the circuit may be represented by Fig. 8. Further, for circuit purposes, the valve itself is just the same thing as a generator (giving a definite A.C. voltage) in series with a resistance (its own anode impedance), so that Fig. 8 can be further simplified into Fig. 9, where R_v is the internal impedance of the first valve, E_{a1} the voltage developed at its anode, and E_{g2} the voltage on the next grid.

First, suppose that Z_g is very large indeed, as is so often stated. In order to make E_{g2} as nearly as possible equal to E_{a1}, we must make Z_a large compared with R_v—as we are always instructed to do. But suppose, as is actually the case, that Z_g is not so very big—that, in fact, Z_g is about the same as R_v (say 20 000 ohms). Z_a and Z_g are two impedances in parallel, and (except under one special set of conditions detailed below) their net impedance will be *less* than that of the lesser of them. So that, however large we make Z_a, we cannot increase the ratio of E_{g2} to E_{a1}, beyond a certain amount—one-half, if $Z_g = R_v$. This is the main reason why resistance coupling (Z_a = a pure resistance) is a failure at low wavelengths, for Z_g decreases with the wavelength.

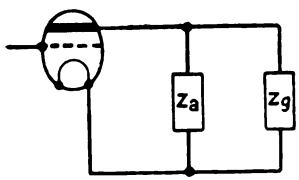

Fig. 8.

There is just one way in which this difficulty may be got over. We have already shown that Z_g is of the nature of a capacity and a resistance. Also, if Z_a is a tuned anode circuit, it can be made of the nature of an inductance and a resistance, as already explained. If, then, the resistances are low, Z_aZ_g becomes really a "rejector" circuit, and may have quite a high impedance if tuned. So we have a further difficulty in tuning the "tuned anode." A certain adjustment may give the strongest signals because (as already explained) it is causing regeneration, or because it is helping to get the previous anode voltage transferred to the grid, or, thirdly, because it is, as shown in this paragraph, helping to get the voltage at its own anode passed on to the *next* grid.

One more point: Adjustment of the second anode circuit alters the grid circuit, and thus alters, as we have explained, the combined value of Z_aZ_g in Fig. 8—*i.e.*, it alters the effective load in the first anode circuit. *But this in turn alters the previous grid circuit, and so on.* In other words, we cannot, as it were, shut up each stage in its own watertight compartment; a change in any stage affects every previous stage right back to the aerial.

It may be asked: Why did we not raise these points in dealing with L.F. amplification? For the simple reason that they are not so important in that case. For audio-frequencies the input impedance is much higher, and the effect of change in load is nothing like so great.

We note with dismay that our allowance of space is up, while we have not yet got down to the "brass tack" side of the business at all. However, we salve our conscience with the thought that this matter of the input impedance of a valve is the foundation of H.F. amplification, and as it has hardly been treated at all in publications available in England, it is as well to have "cleared the air" a little.

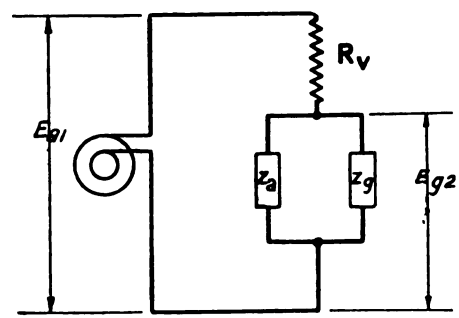

Fig. 9.

Before concluding with a promise of more next month, we must express our indebtedness to the work of Miller, of the Bureau of Standards of America, who worked out the theory of input impedance in relation to output load.

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Measuring H.F. Resistance. [R240

By P. K. Turner.

A brief description of the accepted methods and also of two important new ideas.

IN a paper read before the I.E.E. during January, an interesting method of measuring H.F. resistance was developed by Prof. E. Mallett, M.Sc., and A. D. Blumlein, B.Sc.

Curiously enough, we had just heard of another new method, which turned out to be founded on the same fundamental idea as the above; it has been thought out by Mr. P. W. Willans.

The importance of these methods is that each of them avoids certain difficulties in the usual methods. Briefly, the Mallett scheme is free from certain sources of inaccuracy in most methods, while the

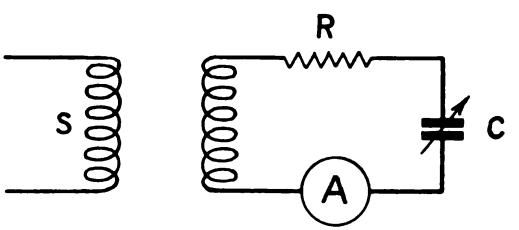

Fig. 1.

Willans method has the especially great advantage of not needing any H.F. voltmeter nor ammeter.

In order to appreciate clearly what is fresh in the two new methods, one must have a clear conception of present ones, and we will therefore devote a few words to consideration of two well-known schemes, the "Resistance - variation" and the "Reactance-variation" methods.

Resistance Variation.

This needs a measuring instrument, and some variable or interchangeable resistances of known values at high frequency. Like all these methods, it measures the resistance of the complete circuit, and gives an "equivalent resistance" including all sources of power loss. As shown in Fig. 1, the circuit is supplied with power from a source S, usually a valve oscillator. The extra resistance R is cut out and C adjusted to resonance, as shown by getting a maximum current at A. This current is noted. R is then inserted and the reduced current reading noted. Calling the first current I_0 and the second I_r, it is easily shown (see Appendix I.) that R_0 (the resistance of the circuit) is given by

$$R_0 = \frac{I_r}{I_0 - I_r} R \quad .. \quad .. \quad (1)$$

In practice, readings are taken for several values of R, and the results analysed either by least squares or graphically. The latter is done by drawing on a large scale a graph of $\frac{1}{I_r}$ against R, which should be a straight line.

This line, if produced till it cuts the axis of R, does so at a point of "negative" resistance, equal to the actual positive resistance of the circuit. Fig. 2 shows a case based on Table I.

TABLE I.

Added resistance. Ohms.	I_r = current mA.	$1/I_r + 100$
0	20	5
1	16·7	6
2	14·3	7
5	10	10
10	6·7	15

(This is an imaginary example: $R_0 = 5$.)

Reactance Variation.

Here again a measuring instrument is needed, but instead of interchangeable fixed resistances we need a calibrated condenser (or variable inductance) and an accurate

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knowledge of the testing frequency. The circuit is that of Fig. 1, but without R.

The procedure is simply to measure the current at exact resonance and also for a given amount of detuning.

It is shown in Appendix II. that if C_r is the capacity in circuit at resonance, C_a the capacity when detuned, and $\omega = 6{\cdot}28 \times$ frequency at resonance,

$$R - A.\frac{1}{\omega C_r}\left(1 - \frac{C_r}{C_a}\right) \quad .. \quad .. \quad (2)$$

where A depends on the ratio between resonant and detuned current, and is given in the following table :—

$\frac{I_a}{I_r}$ =	·707	·446	·316	·243	·164	·124	·1
A =	1	$\frac{1}{2}$	$\frac{1}{3}$	$\frac{1}{4}$	$\frac{1}{6}$	$\frac{1}{8}$	$\frac{1}{10}$

(I_a = " detuned " current, I_r = resonant current.)

Comparisons.

The second method (reactance variation) has the advantage of not requiring a set of known interchangeable resistances, but in practice it is none to easy to get accurate results. In ordinary circuits it may be assumed that R will be about 1/100 of $\frac{1}{\omega C_r}$, which means that either A or $\left(1 - \frac{C_r}{C_a}\right)$ will be small. If we choose a small value of A, we have to read a small current in the detuned position, and few H.F. ammeters are good at the lower end of their range. (We cannot substitute a more sensitive instrument for the second reading, as it would alter R.) If, on the other hand, we keep A at $\frac{1}{2}$ or 1, then $\left(1 - \frac{C_r}{C_a}\right)$ must be about 1/100, or the change in capacity to detune will be about 1 per cent. of the capacity in use. This is near the limit of accuracy of an ordinary commercial condenser, although the difficulty may be dodged by using a combination of condensers.

On the other hand the first method offers some quite appreciable difficulties in the design of the resistances. These must be of fine wire, so that their H.F. resistance does not differ appreciably from that at L.F. The same requirement makes it essential that the power absorption in them is that of a pure ohmic resistance; dielectric losses would make them give false readings. Further, changing one for another must not alter the inductance or capacity of the circuit.

It must not be forgotten that the resistance of the circuit, as found by either of these two methods, includes the resistance of the ammeter. This means that a fairly powerful source must be used, as if one tries to work with a very sensitive meter its resistance is

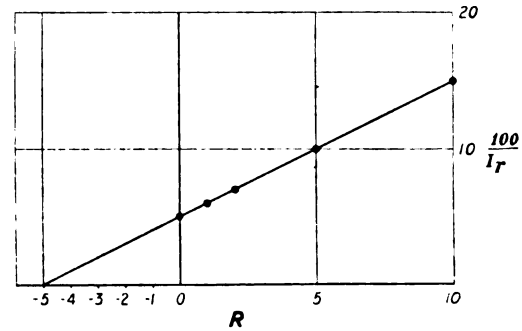

Fig. 2.

so high as to reduce the accuracy of measurement very considerably. For example, an error of 1 per cent. in measuring a resistance of 44 ohms in all, including a 40-ohm thermo-junction, becomes an error of over 10 per cent. in the resulting estimate of 4 ohms for the rest of the circuit.

Increased current must not be got by using closer coupling to the source, for if this is done a change of current in the measuring circuit appreciably influences the source, and the whole system of calculation (which assumes a constant source) breaks down.

For this reason the writer much prefers to use a Moullin voltmeter to measure the voltage across the circuit instead of measuring the current in it.

If the voltage is measured across some part of the circuit which is unaltered during the test—either condenser or coil in the first method, or across the coil in the second method—the ratio of voltages may be used in the equation above in place of the ratio currents with no other change. The power loss in the voltmeter naturally appears as a resistance, but this is extremely low, its apparent series resistance being of the order of 0·5 ohm, while the sensitivity is above that of ordinary thermo-junctions.

A Different Principle.

The two new methods both depend on a rather different principle, and have the

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advantage that they measure the resistance of a circuit without the necessity of any measuring instrument in the circuit. They are allied to the "click" method.

As the mathematical development of the principle involved is really an essential part of the method it is given here instead of in an appendix.

If, as in Fig. 3, we have an oscillating source, and in its neighbourhood a circuit such as A, then currents in the source set up voltages and currents in A. If M is the mutual inductance between the two circuits, $\omega = 2\pi \times$ frequency as usual, and I_1 the current in the source, then the voltage induced in L is $j\,\omega\,M\,I_1$.

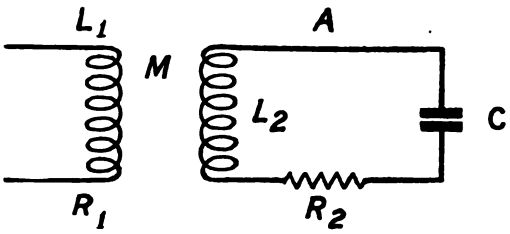

Fig. 3.

The impedance of the circuit A is

$$Z_2 = R_2 + j\left(\omega L_2 - \frac{1}{\omega C_2}\right) \quad .. \quad (3)$$

Taking amplitudes only, we have

$$I_2 = \frac{\omega M I_1}{Z_2} \quad .. \quad .. \quad (4)$$

or using γ as an abbreviation for $\frac{I_2}{I_1}$, we have

$$\gamma^2 = \frac{\omega^2 M^2}{R_2^2 + X_2^2} \quad .. \quad (5)$$

where X_2 is the reactance of circuit A:

$$X_2 = \omega L_2 - \frac{1}{\omega C_2} \quad .. \quad (6)$$

Now it is a well-known principle of transformer action, easily proved, that when a current flows in a secondary circuit (A in this case) the resistance and the reactance of the primary (the source coupling coil in this case) apparently change. If the primary resistance and reactance, without the secondary effect, are R_1 and X_1, then, calling R' and X' the effective values with a secondary current flowing,

$$R' = R_1 + \gamma^2 R_2 \quad .. \quad .. \quad (7)$$

$$X' = X_1 - \gamma^2 X_2 \quad .. \quad .. \quad (8)$$

The essential feature of both the new methods is to utilise as a basis of calculation the change in R' and X' caused by the change in R_2 and X_2 as the circuit A is tuned through resonance.

In the Mallett-Blumlein method Z', the apparent impedance $(= R'^2 + X'^2)$ is measured, and a graphical construction is used to find R_2. A measuring instrument is needed, and a fair amount of work is involved; but great accuracy is claimed.

In the method due to Mr. P. W. Willans, late of the Marconi Co., the source coupling "coil" is actually the pair of coils of an oscillator. The change in X' means a change of effective inductance of these coils, which in turn causes a change in the emitted frequency. This is heard as an alteration of the beat note in phones connected to an oscillating receiver in the neighbourhood (a third and quite distinct circuit, of course). This method may be used either with substituted resistances or by knowing accurately the frequency and condenser calibration, *i.e.*, with the information required for the two older methods; but it has the great advantage of needing no measuring instrument at all.

The Willans Method.

Taking the Willans method first, the change in frequency of the source will be directly proportional to the change of reactance, which is $\gamma^2 X_2$.

But $\gamma^2 = \dfrac{\omega^2 M^2}{R_2^2 + X_2^2}$ (see (5) above)

so that we have

$$\text{Frequency change} \propto \omega^2 M^2 \frac{X_2}{R_2^2 + X_2^2} \quad (9)$$

It is easily proved that (for ωM constant) this is a maximum when $R_2^2 = X_2^2$,

or $$X_2 = \pm R_2 \quad .. \quad .. \quad (10)$$

The actual change in frequency will follow a curve of the shape of that in Fig. 4; no vertical scale is provided, for the "size" of the change will depend on M, the amount of coupling to the source. For reasons to be taken up later, the change must be kept small. Luckily this does not matter, as the beat note method of judging the change is so extremely sensitive.

In this case, the curve is drawn for a value of tuning condenser of ·000 4μF at resonance, giving a condenser reactance of 500 ohms at 377 metres. The inductance coil to tune would be of 100μH. Under

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these conditions, with a value for R of 5 ohms, the curve will be as shown in solid line, and for 10 ohms as shown dotted (the change would be smaller in the latter case, but this is compensated by increasing the coupling).

Translating this curve into sounds heard, and assuming that the condenser tunes to resonance at 100°, we find that on bringing the closed circuit within range, with condenser all out, there will be a scarcely perceptible change in the beat note. As we get nearer resonance the note will change perceptibly (it may be either a rise or a fall, according to whether the separate receiver is above or below the source in frequency). Assuming that it is a rise, we shall find that as we vary the condenser from 95 to 105, the note will rise to a maximum pitch, fall to a minimum, and then come back towards normal. All we have to do is to note carefully and exactly the positions for the highest and lowest notes.

Looking up from the calibration curve the capacities at these points (C_a and C_b), we can easily prove from Equation (10) that

$$2R_1 = \frac{1}{\omega}\left(\frac{1}{C_a} - \frac{1}{C_b}\right) \quad .. \quad (11)$$

One important point must be mentioned. The mathematical argument is based on the assumption that ωM is unchanged. But this is not absolutely correct, for our change in beat note is based on a change in ω. In actual practice, however, this is negligible. For our rise or fall in frequency will be (say) 250 cycles, the beat note varying from 500 to 1 000. Now at 377 metres our frequency is about 800 000, so that the change of 250 amounts to a change of $\frac{250}{800\,000}$, or 1 part in 3 200. This may cause an error of 1 part in 1 600 in our results, which is small compared to other likely errors, for 1 part in 100 is the approximate accuracy of H.F. resistance measurement by such methods.

It is obvious that this method really replaces the ammeter in the normal method described above. If we use it as just described, it is exactly analogous with the "Reactance Variation" method, as will be seen by comparing Equations (11) and (2) above. It is obvious that by our change of beat note we have found the points corresponding to $I_a/I_r = \cdot 707$ when using an ammeter. (See Appendix 2.)

On the other hand, we can use it instead of an ammeter in the "Resistance Variation" method, for if we insert various known H.F. resistances in the closed circuit, and plot $\left(\frac{1}{C_a} - \frac{1}{C_b}\right)$ against added R_1 we get a straight line from which the resistance of the circuit itself can be found exactly as already described. In actual practice it will be found quite accurate enough to plot added R against $C_b - C_a$, which is simpler: in fact if we know that the condenser is a good one, so that the change of capacity for given change of angle is steady, we can actually plot added R against degrees between the two points, and so find the H.F. resistance without knowing what capacity is being used. It is simplest to use the "good" variable condenser as a vernier across a large fixed condenser, to get reasonable sensitivity.

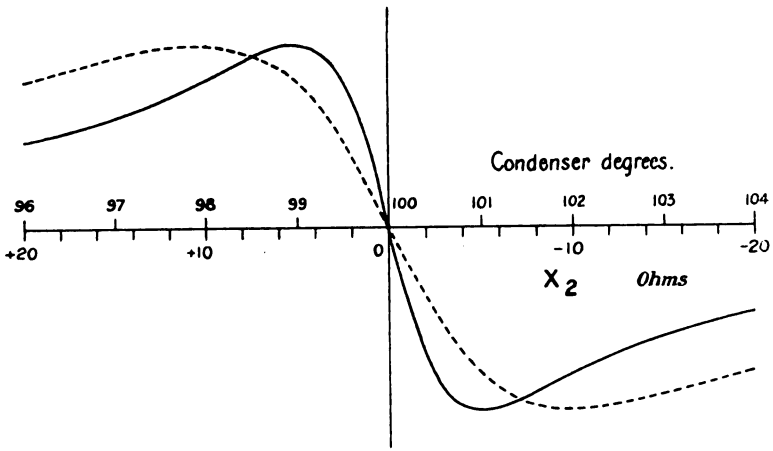

Fig. 4.

All that we need with this method is a set of interchangeable H.F. resistances,

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which can be cheaply made : with them and no other calibrated instrument one can measure H.F. resistance quite well to about 2 per cent.

Further, owing to the great sensitiveness of telephone reception, it can be used with a low-power source (an ordinary small local oscillator).

Incidentally, it might be noted that the mean of the two capacity readings—strictly the harmonic mean—gives a very accurate value for resonance, and so allows us to calibrate a closed circuit without interfering with it by connecting a detector.

A Precision Method.

Now as to the Mallett-Blumlein method. As already stated, this depends on measuring the actual impedance of the source coupling coil.

Going back to Equations (7) and (8), these can be combined into the following form :—

$$Z' = Z_1 + \gamma^2 Z_2 \quad .. \quad .. \quad (12)$$

where Z stands for impedance.

But, as we have shown,

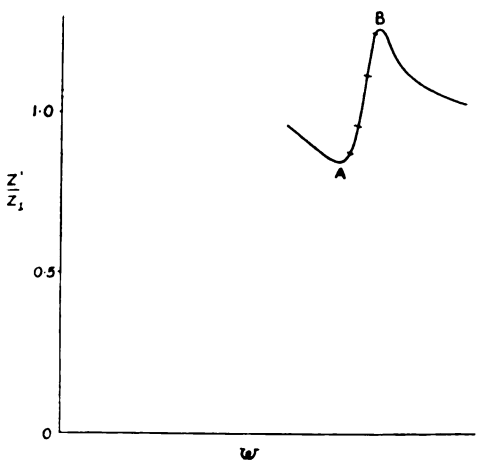

Fig. 5.

$$\gamma^2 = \frac{\omega^2 M^2}{Z_2^2}$$

(see Equation (5) above)

so that

$$Z' = Z_1 + \frac{\omega^2 M^2}{Z_2} \quad .. \quad .. \quad (13)$$

or

$$\frac{Z'}{Z_1} = 1 + \frac{\omega^2 M^2}{Z_1 Z_2} \quad .. \quad .. \quad (14)$$

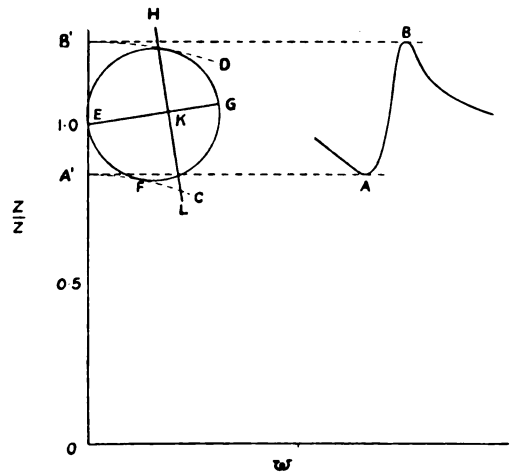

Fig. 6.

Now $Z_2 = R_2 + jX_2$, and so, if we know ω, M, $\frac{Z'}{Z_1}$, and X_2, we can find R_2.

But X_2 is known if we know L_2, the resonant frequency, and ω, and the necessity for knowing M is avoided by taking two readings and solving simultaneously for M and ω. In actual practice a set of several readings is taken and a graphical form of solution employed. We propose to give definite directions as to the graphical solution, its proof being available in the original paper.

The reading to be taken is impedance of coupling coil for various values of frequency : one can either vary the emitted frequency or the "tuning" of the test circuit, the change of natural frequency in the latter case being calculated from the change in capacity. The impedance is also measured with the test circuit broken or removed, and a curve of Z'/Z_1 plotted against ω, as in Fig. 5.

Now, the highest and lowest points A and B of the curve are noted on the left-hand vertical line (A' and B' see, Fig. 6), and with centre O, at the intersection of the axes, arcs $A'C$ and $B'D$ drawn. The circle EFG is thus drawn to pass through the

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point $E\left(\frac{Z'}{Z_1}=1\right)$ and to touch $A'C$ and $B'D$. The diameter EG is drawn, and the line HKL perpendicular to it. The position of this line is not fixed; it may be anywhere along EG, but for choice more or less as shown.

Now we take one by one a series of points on our original curve, and follow out the routine given hereunder for point 2 as an example (see Fig. 7).

First carry the height of 2 straight across to 2': then strike the arc $2'P$ from centre O.

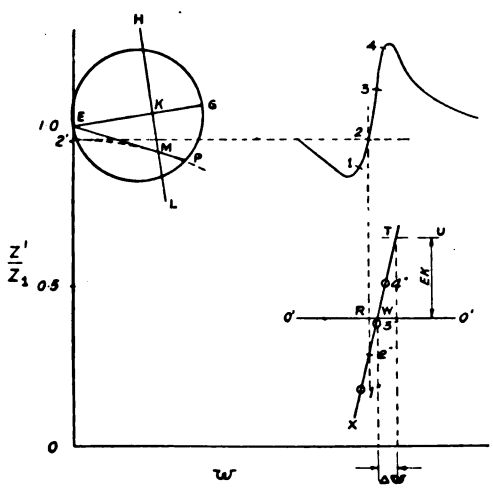

Fig. 7.

Join EP, and note the point M, where EP intersects HKL. Now choose some zero line below the original curve, such as $O'O'$, and directly below the original point 2 set off $R2''$ equal to KM, above or below the zero line according as KM is above or below EG.

The various points thus found, 1", 2", 3", 4", should lie on a straight line. Draw the line (XT) and also draw TU, parallel to the zero line $O'O'$ and a distance equal to EK above it. Measure, on the original scale of ω, the distance $\gamma\omega$, got by projecting downwards the points T and W (the latter being the intersection of XT and $O'O'$). Then

$$R = 2.\gamma\omega.L, \quad .. \quad .. \quad (15)$$

where L is the inductance of the coil in the circuit to be tested.

As will be seen, this method is not altogether simple; but it appears to have important advantages as regards accuracy. It may have a great future for serious laboratory work. The original paper will appear in due course in the *Journal of the I.E.E.*, and should be consulted for full details.

Conclusion.

We fear that these notes on the subject are rather sketchy. It was originally our intention merely to describe the newer methods, but it seemed impossible to make clear wherein lies their novelty without some description of the accepted methods, and we have been led into a longer article than was intended.

As a personal opinion, we are inclined to think very highly of the Willans method, which, while not necessarily more accurate than the older methods, has the very great advantage of avoiding altogether the need of an H.F. measuring instrument, and therefore brings H.F. resistance measurement within the scope of nearly every amateur.

The Mallett-Blumlein method seems also of great importance; but its main claim, that of greatly improved accuracy, is one that can only be proved in the high-class laboratory, and we must wait for reports from such sources before expressing an opinion.

APPENDIX I.

Regarding Fig. 1 (repeated herewith): If the coupling to the source, and the source current, are unchanged, the EMF E induced in the closed circuit is constant.

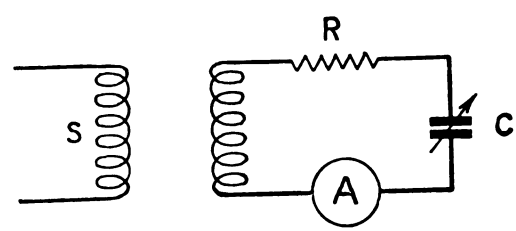

Fig. 1.

Further, as the closed circuit is tuned, its reactance is zero. Hence, if R_0 is the resistance of the circuit itself, and I_r is the current in it

$$I_r = \frac{E}{R+R_0} \quad .. \quad .. \quad (16)$$

When R is cut out, we have a current I_0 given by

$$I_0 = \frac{E}{R_0} \quad .. \quad .. \quad (17)$$

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from (16) and (17) we have

$$E = R_0 I_0 = R I_r + R_0 I_r$$

$$\text{or } R_0 = \frac{I_r}{I_0 - I_r} R \quad .. \quad .. \quad (18)$$

APPENDIX II.

If Z is the impedance of the closed circuit, we have

$$Z = \sqrt{R^2 + X^2} \quad .. \quad .. \quad (19)$$

where X is the reactance, and is given by

$$X = \omega L - \frac{1}{\omega C} \quad .. \quad .. \quad (20)$$

Now, as in Appendix I., E is constant, and

$$I = \frac{E}{Z} \quad .. \quad .. \quad (21)$$

At any particular setting of the condenser, giving a capacity C_a, we have a corresponding reactance X_a, and a current I_a, while at resonance we have $X = 0$, and

$$I_r = \frac{E}{R}$$

Hence

$$\frac{I_r}{I_a} = \frac{Z_a}{R} = \sqrt{1 + \frac{X_a^2}{R^2}} \quad .. \quad (22)$$

or

$$\frac{X_a^2}{R^2} = \frac{I_r^2}{I_a^2} - 1 \quad .. \quad .. \quad (23)$$

or

$$R^2 = \frac{I_a^2}{I_r^2 - I_a^2} X_a^2 \quad .. \quad .. \quad (24)$$

Now at resonance, as already stated, $X = 0$ or

$$\omega L = \frac{1}{\omega C_r}$$

Therefore, at any other setting,

$$X_a = \frac{1}{\omega}\left(\frac{1}{C_r} - \frac{1}{C_a}\right) \quad .. \quad .. \quad (25)$$

or, from (24)

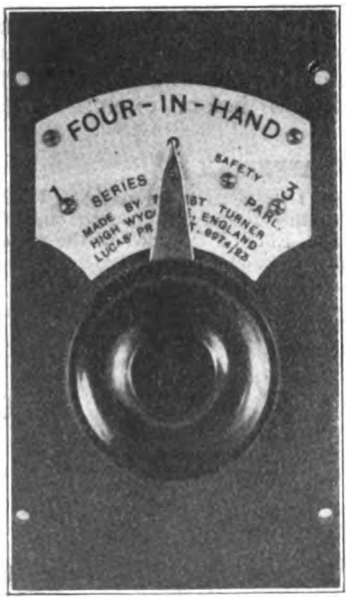
$$R = \pm \sqrt{\frac{I_a^2}{I_r^2 - I_a^2}} \cdot \frac{1}{\omega C_r}\left(1 - \frac{C_r}{C_a}\right) \quad .. \quad (26)$$

The factor A in Equation (2) is

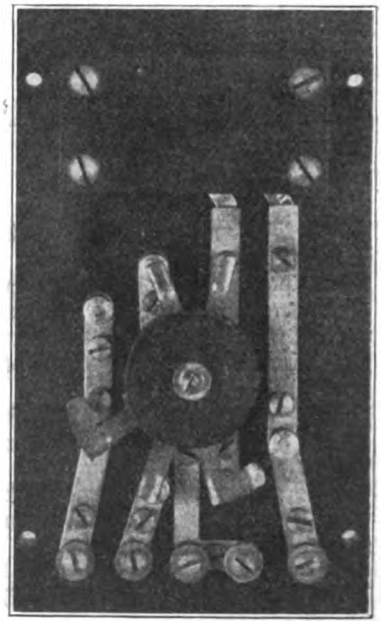
$$\sqrt{\frac{I_a^2}{I_r^2 - I_a^2}}$$

and the $\pm$ sign allows for the fact that the detuning may be on either side of resonance, so that C_r/C_a may be either greater than 1 or less: in either case we take a positive value for R.

A Useful Series-Parallel Switch.



It is often very useful to be able to switch over one's aerial condenser from series to parallel, but the advantage is trebled if by so doing an overlap in wave-length can be obtained without altering the aerial coil. This fact has been realised by Mr. Ernest Turner, of High Wycombe, who has patented an arrangement a back and front view of which is reproduced herewith.



The five terminals at the foot are connected to the aerial, variable condenser, aerial end of the tuning inductance and earth respectively; and by means of the multiple switch shown, the variable condenser can either be connected in series with the aerial (first position), or a small fixed condenser (about ·000 5) can be placed in shunt with the tuning inductance when on stud two. In position 3 (safety) aerial and earth are shorted, while the fourth places the variable condenser in parallel with the inductance—the fixed condenser being shorted.

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Oliver Heaviside, F.R.S.

A Founder of Wireless. [R097

ALL our readers will know of Oliver Heaviside, for the "Heaviside layer" is a commonplace among them; but we propose to give a few words to the other work of this great man, so long misunderstood that when at last appreciation came to him he was beyond enjoying it.

In some ways Heaviside was the typical scientist of fiction and alleged humour—a king at his work, but lost in public; and rather prone to fight his brother scientists. In this last matter, however, there is much to be said on his behalf, for he was so much in advance of his time that his work for a long period received a reception unworthy of his fellows and to the last degree embittering to himself.

Always of eremitic temperament, his desire for solitude was accentuated by these troubles, and his "life" apart from his work presents few features. He was born in 1850, and his early work was done in Kentish Town, London. It was not well received at first, but eventually received recognition. But he would not stay to enjoy this late appreciation: he moved down to Devonshire, where he lived alone in a cottage, only meeting his fellow men on his periodical visits to the nearest village for food. He lived without help of any kind and apparently with very little means.

By 1891, the scientists of his day had begun to find the value of his work. In that year he was elected a Fellow of the Royal Society. Later he was made Hon. Ph.D. of Göttingen, and Hon. Member of the American Academy of Arts and Sciences. In 1922, on the establishment of the Faraday Medal (to commemorate the 50th anniversary of the "Society of Telegraph Engineers," which was the first title of the I.E.E.), the highest honour of the institution, it was decided to confer it first upon Heaviside.

A few weeks ago it was stated that he had quite by chance been found very ill and removed to hospital. He did not recover.

His Work.

In spite of the fact that the amateur will usually connect his name with the famous "layer," all wireless workers will have come

A striking photograph of the late Dr. Oliver Heaviside, F.R.S., whose recent death will be lamented by scientists throughout the world.

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in touch with his work at an earlier stage in their knowledge. For it was Heaviside who actually invented the word "inductance." He had to do so, for he was the first to carry out a thorough investigation of the thing now called by that name. Kelvin, it is true, had an idea of this entity, but had not really dealt with it. Heaviside also coined the words "reluctance," "reactance," and others now in regular use.

In the course of the work for which he invented these words he developed the whole theory of telegraphy on wires, showing first that signals are propagated as waves, and do not simply leak along the wires as it were. He went beyond this, and took hold of Clerk-Maxwell's famous theory of radiation, invented a new mathematical system to deal with it, and extended it. His work on wire telegraphy indicated that improved results would be got by artificially increasing the inductance of the line. The idea was dismissed with scorn by the telegraph engineers of this country, and it was left to Pupin, in America, to develop the practical application in conjunction with the American Telegraph & Telephone Co., so that the loading coils now in general use for long line work—which have made real long-distance telephony possible—are known as Pupin coils instead of being called by the name of Heaviside.

It was in his investigation of radiation that he tackled the problem of how and why "free" waves (such as those used in wireless) may be actually tied down to the conducting surface of the earth, and in this connection he suggested that as the upper layers of the atmosphere get less and less dense there must come at a certain height a layer which is not an insulator but a gaseous conductor. This layer, he pointed out, would be a guide or a reflector for waves, and the view now generally held is that only by means of this layer do we achieve long-range wireless working.

It is true that a German scientist is stated to have developed an hypothesis which accounts for long-distance work without the Heaviside layer, just as, for many years, some chemical professors of that nation have refused to mention atoms because the Englishman Dalton was entitled to the credit of the atomic theory. Recently the work of Sir Joseph Larmor has further elucidated the mechanism of the layer, and there seems little doubt as to Heaviside's foresight in this as in everything else that he handled.

It is interesting to note the opinions expressed on Heaviside by his colleagues when, in later days, they had understood his work. An official tribute was that of J. S. Highfield, President of the I.E.E., in his message covering the first Faraday Medal :—

"In the course of the meetings they [the I.E.E.—Ed.] have been again reminded of, and have recognised, the great importance of the classic work achieved by Mr. Heaviside and published by him in his papers and writings from 1887 onwards, and especially of his discovery of the importance of Inductance in circuits for the transmission of telegraph and telephone signals without distortion ; and of him as the originator of the methods now universally employed for this purpose ; and in no less a measure of his investigations and discoveries relative to the propagation of electro-magnetic waves in space, the results of which are now being utilised in Wireless Telegraphy and Telephony. They are convinced that, as now, so in the future, the name of Heaviside will rank among those of the great founders of the Science of Applied Electricity."

And lest we feel too much the injustice that he suffered, we can conclude in the sympathetic words of Sir Oliver Lodge—one of Heaviside's few friends—in *The Electrician* of February 13 :—

"I do not think the man was unhappy ; though at one time he was rather embittered by the misunderstanding and hostility of those in authority—an attitude which a genial man like Sir William Preece would have been the first to lament had he been better informed. Heaviside lived an independent, self-contained life : and no doubt his insight into Nature (whether recognised by his contemporaries or not) must have given him moments of sincere pleasure. The least we can do now is to recognise his genius, and wish that it had been earlier recognised and more widely known."

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Radio 2GW. An Amateur Station.

By J. Allan Cash. **[R612**

Aerial Experiments.

RADIO 2GW is, unfortunately, situated out in the wilds of Cheshire, where no electricity is obtainable. So the tale of its growth may interest other amateurs in this predicament who are, like the writer, not very "wealthy," and yet who want to become known in Europe. Most of the workable countries of Europe are now acquainted with this station.

During the last few years many and varied aerial systems have been tried. The house in which 2GW is situated is somewhat tall, so it has been a fairly easy matter to obtain a good aerial.

received, declared emphatically that it could not be so, as he could see that the wires did not reach to Paris !

This aerial sufficed for some time, but a lot of trouble was caused through the aerial wires not being strong enough to hold back the tree when it swayed in a gale !

Then a 20-ft. flag-pole was fastened in another tree, and the aerial swung round and up to it, making it 45 ft. up at the house end, and 57 ft. at the tree end. This was a decided improvement, but the writer is never satisfied, so some 22-ft. hollow spars were obtained from Southport, 40 miles away, and brought in on a touring car.

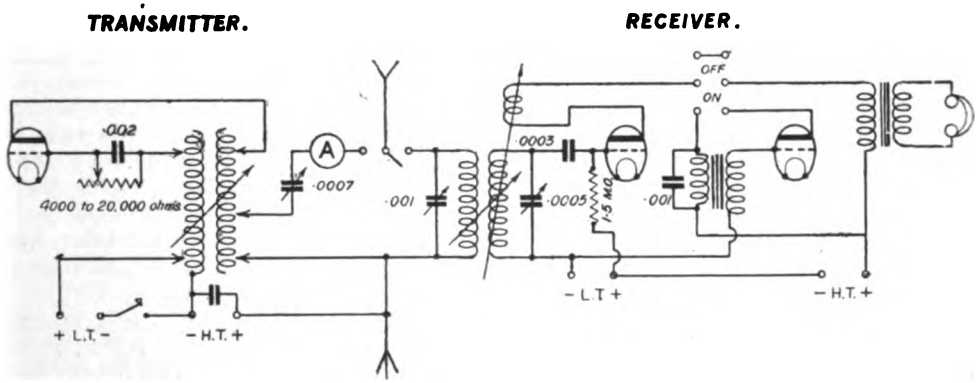

Fig. 1.

Schematic diagram of the circuits at present in use at 2GW.

At first a chimney stack and a tree were used, and a twin-wire aerial slung between them—to the utter amazement of the neighbourhood, by the way, as wireless was an unknown quantity to most people in those days. Then a 15-ft. mast was fixed on the roof, and the same aerial slung to it.

It was after this that a sorely puzzled neighbour, hearing that Paris had been

Two of these poles were bolted together, and with much careful balancing and roof-crawling, the whole 40 ft. mast was secured on the roof.

A convenient chimney-stack was found, just about the middle of the roof, and the eleven stay wires were taken to the four corners of the house. In this way no stay was more than 50 ft. long, whereas if they

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had been taken down to Mother Earth, some of them would have been quite 90 ft. long. All stays were split up with insulators every 20 ft. and at both ends.

This looked really "posh," and some admiring neighbours immediately christened the house "Lusitania." Whether this was a bit of sarcasm, in view of the fact that

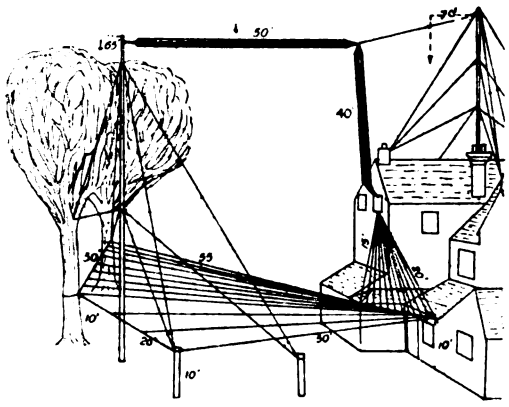

Fig. 2.

This sketch illustrates 2GW's earth and aerial systems, and gives accurate measurements, while—

the *Lusitania* went "down," has never been ascertained. However, various people predicted that the aerial would come down as soon as the wind so much as looked at it; but I am glad to say that it has remained erect successfully for seventeen months.

The tree end still swayed badly, although now only sideways, and in the end it was decided to scrap trees once and for all, and two larch poles, one 42 ft. and the other 32 ft. long, were obtained. These were stripped, painted and bolted together, and a hollow spar fastened on the end, making an 82 ft. mast. It was a big jog getting it up, but when it did point skywards, it was "some stick." Unfortunately, however, the back stays could not be brought out at a big enough angle, and the top length gave up the ghost in a terrific gale. Now, to serve until something better turns up, the larch-poles have been re-erected; and they make a very fine 65-ft. mast.

The aerial now in use is a six-wire cage. The wire is 7/26 S.W.G. hard-drawn copper, and the hoops, 12 in. diameter, are made of ¼ in. aluminium 10d. These latter were made locally, and a rather larger number than necessary had to be procured. A few are still available at cost price, if any enthusiastic amateur would care to try them. The aerial is 50 ft. long, and the lead-in 40 ft., both being caged in the same manner. The lead-in tube is of thick ebonite, and the lead to the change-over switch is of ¾ in. copper strip, four feet long.

A twelve-wire counterpoise is now used, and is far better than any earth ever in use at 2GW. This is fanned downwards from the window of the "den" to a strong piece of wire 12 ft. long. Then the wires are fanned to about 40 ft., each one being about 70 ft. long altogether. Every wire is carefully insulated, and the counterpoise is about 10 ft. from the ground.

So much for the outside. Now let's get in out of the rain!

Difficulties Encountered—and Overcome.

Many different sets and circuits have been employed, and wave-lengths of 1000 metres, 440 metres, and 200 metres, in turn were used, according to the fancy of H.M. Postmaster-General. Small dry cells were used for H.T. on the first few transmitters, and quite good work was done on them. It was only when really low wave-lengths were becoming "fashionable" that the flash-lamp battery was finally abandoned.

Some little time ago a Wilson break was obtained from 2PC, and the necessary junk gradually obtained for using it. A very well made ex-Government transformer was kindly given to the writer by 2WO. The primary of this was re-wound to give, as nearly as possible, 1500 volts off the secondary with 20 volts input. The transformer was designed for 500 cycles, so it was hoped that something would happen.

The "juice" of 24 volts in accumulators (borrowed from all the B.C.L.'s in the district) was put on to the break, and the transformer connected. The motor alone took only ·25 amp to run light. To test the transformer, we shorted the secondary. If it came through, we thought we could rely on it! It came through with flying colours—and sparks! The amps went up to four, but there was no sign of a breakdown anywhere.

So that was that, and the transformer is still in use. Another one, designed rather more accurately, is now being made, with various voltage taps.

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The Transmitting Circuit.

The whole transmitter was then rigged up and tested. After a few alterations the aerial ammeter slowly crept round a little way. Great hopes were entertained till suddenly a sharp crack was heard in the dim interior of the set, and shocks were felt on touching any single thing. The plate condenser had blown up, but as it was only a 1 000 volts condenser, this can be excused. Then a condenser off a spark set (supposed to stand 50 000 volts) was used and this blew up, too!

About this time summer holidays asserted their authority. On returning, however, from this necessary evil, the writer set to and re-hashed the set, rigging up another circuit. A condenser had been made up by scrapping a 1μF mica condenser (Government junk) and putting five sheets of mica between each plate instead of one. This was sure F.B., and the set worked almost immediately.

On 130 metres the first night, Holland, Sweden and South France were worked, as well as various English stations. The aerial current was only ·13 amp, and will not go up at all unless a bigger voltage is used. Probably the new transformer will tickle its imagination a little, but it is a curious fact that, all along, comparatively small aerial currents have been obtained at 2GW, even though different ammeters have been tried.

Of course the high aerial has something to do with it. Ranges up to 1 000 miles can be obtained with only 20 volts input, which give ·11 amp in the aerial. When 30 volts are used, all Europe seems to answer a call!

No attempt has been made to rectify the plate supply yet, but this may be done later on.

The receiver at 2GW was the result of a determined attempt to make a really efficient short wave set. It was decided to put the components as nearly as possible in the order that they come. Also connecting wires were to be as short as possible. The standard coupled circuit is used with detector and one-step.

Much good work has been done by the writer with H.F. amplifiers, but it has now been decided that it is easier to read weak signals with very little QRM, than stronger signals with all sorts of weird noises thrown in. Everything that H.F. amplification brings in can be heard on one valve if the set is properly designed.

The Receiver.

The low-wave coils are all home-made. They are single-layer inductances wound with 22 S.W.G. enamelled wire. A set of these (6) has been made with 5, 7, 10, 15, 20 and 30 turns respectively. They will reach well below a hundred metres without any trouble. Special low-loss coils are being made to go down lower still.

Dubilier condensers are used throughout, both fixed and variable. The coil mount is a product of the Manchester Radio Co., Ltd., as are also the L.F. and phone transformers.

A home-made heterodyne wavemeter is always connected up by the side of the receiver, and all amateur waves can be given instantly.

The receiver has done all that was expected of it. Countless American amateurs have been received, mostly on one valve. Argentine CB8 was once received, while KDKA was always easily "readable" on 100 metres with one valve, and with two was nearly loud-speaker strength. Occasionally (but not often, let it be known) broadcasting is received, and all the big stations and most of the relay stations can be heard on only one valve. In fact, the writer often wonders why there is an amplifier at all!

It is not claimed that 2GW is as perfect as it could be, but as it is rather novel in some respects, and as almost everything is home-made, it was thought worthy of a description. QSL cards and letters are always answered immediately, and a complete log book of all work is kept. Fading curves of many stations are often taken (when they stay on long enough); but extensive experiments in fading have shown that the best are those which come in over-sea—either the North Sea or the Atlantic.

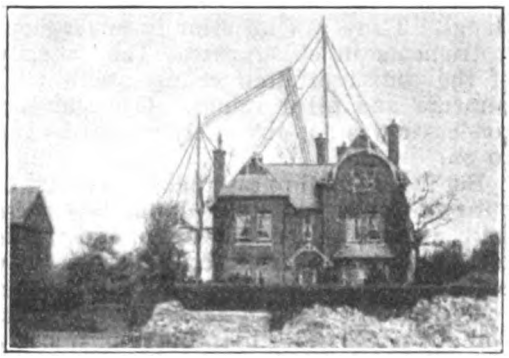

Fig. 3.
—this shows the actual appearance of the aerial

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Error in Measurements.

[R800 : R519

By P. K. Turner.

A very simple explanation of how one finds the estimated accuracy and most probable true value of a measured quantity.

NO measurement is ever accurate, except by pure accident. True, errors in measurement are sometimes very small. The N.P.L., it appears, can check a wave-length—or, rather, a frequency—to within one part in 100 000, or a resistance to even greater accuracy; but, even so, the measurement is not given as absolutely correct, and this article is an attempt to set out some of the simpler ways of handling the results of measurements to get the smallest error and to find what that error is. We do not propose to deal with the actual details of the measurements.

Suppose that, by any method, we have measured a fixed condenser, and find its capacity to be ·001 5μF. All that we can say is that its true capacity is *about* that. We can only guess how close to the measured value by previous knowledge of how accurate the method used is likely to be. Suppose we measure it again, and find it ·001 4μF. What has happened? Any one of many things. There was an error in reading our instruments in either case. The capacity of the condenser itself changes with temperature and other things. Our standard condenser was not absolutely constant—and so on.

But it is natural to say that the average of our two results (·001 45μF) is the best guess we can make at the true value, and this is really true under certain conditions, as may be shown mathematically. The "certain conditions," as far as ordinary testing goes, boil down to two—that the results, ·001 4 and ·001 5, should be read directly and not calculated from other readings; and that, as far as one may judge from the conditions of test, they are of equal closeness and accuracy.

This latter point is an important one. Suppose that we are testing a condenser believed to be of ·000 2, by substituting it for a variable condenser in an oscillating circuit in the well-known manner. Suppose, also, that we have two calibrated standard condensers, one of ·000 2 and one of ·001, and that we make a test with each of them. The small one would be used "all in," and an error of half a degree in setting or reading it would give an error of $\frac{1}{2} \times \frac{1}{180}$ part in 1, or about $\frac{1}{3}$ per cent.

With the large condenser, it would be set at about 36°, and the same error of half degree in setting or reading would result in an inaccuracy of $\frac{1}{2} \times \frac{1}{36}$, or about $1\frac{1}{2}$ per cent. So that the first test is five times as accurate as the second, and an average of the two results would not be the best guess at the true value. This point, however, we must leave aside for the moment.

Going back to our first test—a condenser of about ·001 5—we got, let us say, two results—·001 5 and ·001 4. Now suppose, by another method, we got two results—·001 45 and ·001 46. We should naturally conclude that the latter method was the more accurate one, and that the error in the result was probably much less. We can, in fact, calculate the "probable error" in either case, and the calculation is a quite simple one.

But we must first define "probable error."

Probable Error.

One is inclined to think, from the two results of ·001 4 and ·001 5, that the correct value is ·001 45, in which case the error in either reading is ·000 05. But we cannot state this definitely. It is quite probable that the true value is ·001 47, for example, one error being ·000 03 and the other ·000 07; and it is *possible*, though not probable, that the real value is ·001 6, with errors of ·000 1 and ·000 2. It is correct to say that in this case errors above ·000 1 or so are unlikely, or the two values found would not have been so close together. If we could hit on the correct figure, we might be able to say truly that there was an equal chance of the

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error being smaller or larger than this amount; and this is what we do in giving the "probable error."

Another point. If we make several measurements of the same condenser or other device, and each measurement has a "probable error" of a certain amount, we are safe in saying that the average of all our results is a much more accurate guess than any individual measurement, *i.e.*, its probable error is less.

To show how we find these errors, we will take a numerical example. Suppose we make six measurements on the same condenser, with the following results :—

TABLE I.

	·001 50
	·001 40
	·001 48
	·001 40
	·001 41
	·001 39
Average	·001 43

The first thing is to find the average in the usual manner (add the results and divide by the number of tests). This has already been done in Table I.

Next, find the difference of each result from the average, as in the second column of Table II. It is a useful check to note that if the averaging is correct the sum of positive errors must equal that of the negative.

TABLE II.

Readings.	Errors.	Errors Squared.
·00150	+ 7	49
·00140	− 3	9
·00148	+ 5	25
·00140	− 3	9
·00141	− 2	4
·00139	− 4	16
Av. ·00143	+12 −12	Sum 112

Now square each error, and add the squares all together. This amounts to 112 in our case (remember that we have omitted a decimal point and string of 0's). To find the probable error of one reading, divide this 112 by *one less than the number of tests*—

$$112 \div 5 = 22{\cdot}4$$

Then take the square root—

$$\sqrt{22{\cdot}4} = \underline{4{\cdot}84}$$

This is the probable error of a single reading. It is more useful, as a rule, to have the probable error of the average. This is found in the same way, but after dividing by one less than the number of tests, we divide by the number of tests :—

$$112 \div 5 = 22{\cdot}4$$
$$22{\cdot}4 \div 6 = 3{\cdot}73$$

and then extract the square root—

$$\sqrt{3{\cdot}73} = \underline{1{\cdot}93}.$$

Remembering that our errors of +7, − 3, etc., were really ·000 07, ·000 03, etc., we see that the probable error of our average is ·000 019. We usually say "the capacity is ·001 43±·000 019," or we can express the fraction $\frac{\cdot 000\,019}{\cdot 001\,43}$ as 1·3 per cent., and say ·001 43±1·3 per cent.

Indirect Measurements.

Other cases which arise cannot be dealt with in quite this simple way. Suppose, for example, we want to find the H.F. inductance of a coil. We put it across a calibrated condenser, and find the wave-length of the combination.

Then, *if the coil had no self-capacity*, we

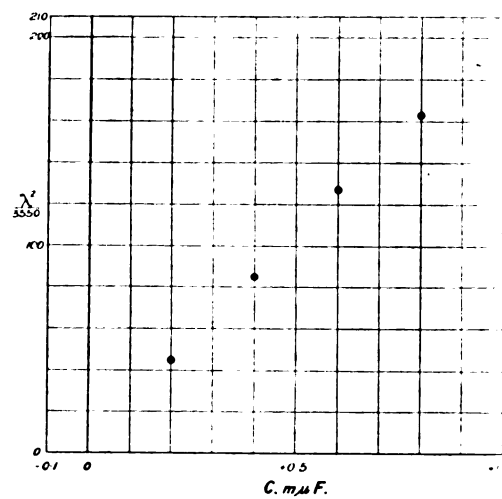

Fig. 1.

could find its inductance from the old formula for inductance, capacity, and wave-length. But the coil *has* self-capacity, of value unknown, and we must allow for this. The calculation is best shown in the form of

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elementary algebra. If L is the inductance and C_T the total capacity, we have

$$\lambda = 1\ 885\ \sqrt{C_T L}$$

if C is in microfarads and L in microhenries.

This can be re-stated as

$$C_T L = \frac{\lambda^2}{3\ 550}, \text{ with } C_T \text{ in m}\mu\text{F.}$$

$$(\cdot 001\mu\text{F} = 1\text{m}\mu\text{F.})$$

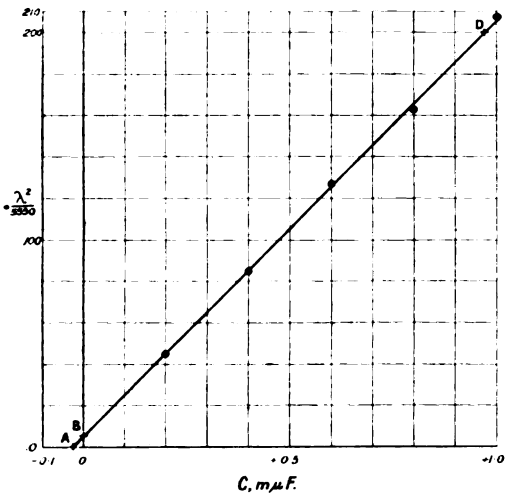

Fig. 2.

Now, if the self-capacity of the coil is C_s, and we make two tests with different values, C_1 and C_2, of the condenser, giving λ_1 and λ_2 as wave-lengths, we have

$$LC_1 + LC_s = \frac{\lambda_1^2}{3\ 550}$$

$$LC_2 + LC_s = \frac{\lambda_2^2}{3\ 550}$$

From these two equations we can find L and C_s, the two unknown quantities.

But in all probability we shall take several readings, not only two; and if we take the results two by two and find L and C_s from each pair, we shall get different results. How shall we find the most probable values? Well, for accurate purposes there is a perfectly definite method, that of "Normal Equations," which will be found treated in works on the "Method of Least Squares." But it involves a fair amount of work, and I do not propose to explain it unless readers of E.W. & W.E. ask for it. One can arrive at a fair approximation in a simpler way graphically.

This graphical method is simple, but depends to a great extent on skill in use. We first have to arrange our results in such a manner that when plotted in a graph they fall on a straight line. In the above case, we want to plot wave-length against added capacity (λ against $C_{1,2}$ . . . etc.). But this will not give a straight line.

Perhaps it is hardly necessary to explain that in order that x and y shall give a straight line, the equation connecting them must be of the form

$$ax + by + c = o,$$

or some equivalent form; it must not contain xy nor x^2 nor y^2, nor any other power, nor sin x nor log x—nothing, in fact, but simple x and y and constants. Now the equation under consideration is of the form (remember that C and λ correspond to x and y)—

$$LC - \frac{1}{3\ 550}\lambda^2 + LC_s = O,$$

where L and C_s are constants.

But suppose that instead of plotting C against λ, we plot C against λ^2. Then we *shall* get a straight line. We shall actually get a series of points, something like Fig. 1. If now we draw a straight line as nearly as possible through these points, we get Fig. 2. Now consider the points A and B. At A we have $\lambda = o$. From our equation, this gives $LC + LC_s = o$, or $C_s = -C$. In words, the negative capacity, as read on the scale, is the self-capacity of the coil. At B, $C = o$, and we thus have, from the same equation,

$$L = \frac{\lambda^2}{3550 C_s}, \text{ which gives the true inductance.}$$

The real difficulty is to hit on the straight line which lies most truly among the points.

The case shown in Fig. 2 is from the experimental results of Table III.

TABLE III.

Test of an inductance with various capacities across it.

Added capacity, C (mμF)	Wave-length (metres).
1·0	860
·8	760
·6	672
·4	550
·2	398

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This particular case was worked out graphically, and gave, on the original large-scale drawing, $C_s = \cdot 028 m\mu F$ $(= 28 \mu\mu F)$. At B, $\frac{\lambda^2}{3\,550}$ was 5·5, and this, divided by C_s, gave $L = 196$. But a more accurate way of finding L is to take some point higher up the line, and divide $\frac{\lambda^2}{3\,550}$ by $C + C_s$. Thus if $C = \cdot 972$, $C + C_s = 1$. At this point, marked D, $\frac{\lambda^2}{3\,550}$ is exactly 200, and L is therefore 200.

Further, we can arrive at some idea of the probable error by seeing how closely the points lie on the line. In this case, two points are about 3 units below or above the line, at values on the scale of about 150 and 200, we can therefore estimate the accuracy, quite roughly, as 2 per cent. or so, for L. This is also the accuracy for $(C + C_s)$, and as C is nearly 1 and C_s is only about ·03, a 2 per cent. error in $(C + C_s)$ would involve a $\frac{1}{\cdot 03} \times 2$ or 66 per cent. error in C_s. Hence we can only claim 66 per cent. as the accuracy of C_s.

An actual investigation, by the normal method, gave the following values :—

$L = 202 \pm 3 \cdot 7$ (= 2 per cent. approx.).

$C_s = \cdot 021 \pm \cdot 012$ (= 60 per cent. approx.).

Valve Designations.

A Suggestion for Standardisation of Markings.

SINCE the introduction of the dull emitter valve there has been a very rapid increase in the number of different types of valves (as distinct from different *makes*) available to the public. We imagine that this is the natural consequence of the fact that users are now beginning to learn that a general purpose valve, while an excellent compromise, naturally cannot do so well as a series of separate valves each designed for its special purpose. There is also the fact that the use of power valves was previously limited, owing to the high current consumption—the very much lower input needed for dull emitter valves has made the use of power valves more practicable on the ordinary receiver. It is, however, an unfortunate fact that while in most cases several of the important makers have put on the market valves having practically identical characteristics, they have not only given these valves different key letters—B for the B.T.-H. valves, D.E. for the Marconi-Osram, and D.F.A. for Mullards, etc.—

We regret that in the article, "Power Amplification for Loud Speakers used at Wembley," which appeared in our last issue, no acknowledgement was made to Messrs. Alfred Graham & Co., whose Amplion "Goliaths" were used. Above we show a corner of the Exhibition with one of the loud speakers in the foreground.

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but they have not in any way systematised the key numbers.

For example, the type of power valve taking 0·25 amp at 5½ to 6 volts is called the B.4, D.E.5, or D.F.A.1 by its various makers, while the well-known 60 milliamp type is known as B.5, D.E.3, or D.06. Some weeks ago, we wrote a letter to the Valve Makers' Association calling attention to the fact that this was causing endless confusion among users, and suggesting that there would be no real difficulty in the way of adopting a uniform numbering scheme, while maintaining the individual letters as distinguishing features for each maker. We also submitted a scheme carrying this out, which appeared to have advantages.

We were informed by the Valve Makers' Association that the scheme was being favourably considered, but up to date no conclusion seems to have been reached. We have, therefore, decided that we will publish the scheme, with the hope that even if the valve makers do not of their own initiative set it in operation, it will be useful to users; we ourselves propose to use this method of describing valves in future issues.

Briefly, the idea is to substitute for the key numbers of individual makers a three-figure number, of which the first figure shall indicate the approximate rated voltage for the filament, and the last two figures the rated current. Thus the type of valve already referred to, which is designed for 6 volts and takes 0·25 amp, will be known simply as a 625 valve. Our suggestion to the Valve Makers' Association was that each maker should place in front of this number his own key letters; but for journalistic purposes it is usually desired to indicate a type of valve without specifying the particular maker, and for this purpose the figures alone will serve. In one or two cases where valves are made with the same input, but designed to give specially high or low magnification, we propose that the Association should follow the practice already in use to a certain extent, and put after the number a small letter—"a" in the case of valves of extra low magnification, and "b" in the case of extra high magnification. The Marconi-Osram valve taking 6 volts and 0·25 amp with a magnification of 20 is at present known as the D.E.5b, and we suggest that this would be known as the 625b type. The table below gives the majority of valves in common use to-day, divided into types, with the names given them at present by their various makers, and our suggested type numbers. It is obvious that one can continue to elaborate the type numbers to include reference to magnification, output current, and so forth, but we do not consider that this would be an advantage.

Type and Description.	Price.	Present Key Letters and Numbers.					Suggested Type No.
		B.T.-H.	Cossor.	Ediswan.	M.-O.	Mullard.	
Bright G.P.	11/-	R	P 1, P 2	A R., R.	R., etc.	R., Ora, H.F., L.F.	**460**
5-volt G.P.	11/-	—	—	—	R.5v	—	**560**
"Semi-dull" G.P. ..	18/-	B.3	—	A.R.D.E.	D.E.R.	D.3, H.F. and L.F.	**235**
Special Ditto	18/-	—	W.1. & 2	—	—	—	**225**
	20/-	—	W.R.1 & 2				
·06 or 60 milliamp ..	21/-	B.5	—	A.R.·06	D.E.3	D.·06, H.F. and L.F.	**306**
Weco	21/-	—	—	—	—	Weco	**125**
6-volt D.E. Power ..	30/-	B.4	—	P.V.5D.E.	D.E.5	D.F.A.1	**625**
Ditto, High Magnification	30/-	—	—	—	D.E.5b	D.F.A.4	**625b**
4-volt D.E. Power ..	26/-	—	—	—	D.E.4	D.F.A.0	**435**
Low-current Power ..	32/-	B.7	—	—	—	D.F.A.3	**606**
2-volt Power	22/6	—	—	—	D.E.6	—	**245**
3-volt Power	30/-	B.6	—	—	—	—	**312**

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Notes on the New Bill.

From every point of view the new Wireless Bill at present before the House is bad for serious amateurs, as the extracts and our comments below will show.

THIS new Bill may be considered as one of the cleverest examples of oppressive legislation that has ever been drafted. For it contains a bold clause—that dealing with the searching of houses—which has attracted everyone's attention. Unless great care is taken, other and much more serious interference with wireless work will slip through uncriticised, while the Press and the public are chasing a red herring.

We have, first, Section 1, which follows the old Act in stating that :—

> A person shall not establish or maintain any wireless telegraph station, or install, work, or maintain any apparatus for wireless telegraphy, in any place or on board any ship or aircraft to which this Act applies except under and in accordance with a licence granted in that behalf by the Postmaster-General.

This, of course, is from the old Act ; and as there are sound reasons why wireless must be controlled by some Government Department, there is no comment to be made.

Section 1 (3) defines the maximum penalties for offences under the Act. They are heavy, but this is not so important as has been stated in the lay Press, for, after all, the actual penalty inflicted in any given case is decided by a magistrate or judge, who only inflicts heavy penalties when they are really called for.

Section 1 (4) is the "search" clause which has caused such a flutter. Why, we cannot think, for there has always been the right of the police to apply to a magistrate for a search warrant if they have information that premises are being used for any of quite a long list of unlawful purposes. According to the "Dailies," one conjures up visions of any Post Office official having the right to enter premises at his own sweet will. What the Bill actually says is :—

> If a justice of the peace is satisfied by information on oath that there is reasonable ground for supposing that a wireless telegraph station has been established, or is being maintained, without a licence in that behalf, or that any apparatus for wireless telegraphy has been installed, or is being worked or maintained in any place or on board any ship or aircraft within his jurisdiction without a licence in that behalf, he may grant a search warrant to any police officer or any officer appointed in that behalf by the Postmaster-General, the Admiralty, the Army Council, the Air Council, or the Board of Trade and named in the warrant, and a warrant so granted shall authorise the officer named therein to enter and inspect the station, place, ship or aircraft and to seize any apparatus which appears to him to be used, or intended to be used, for wireless telegraphy therein.

It will be seen from this that the powers are not excessive at all.

Section 1 (5) reads :—

> The expression "wireless telegraphy" means any system of communication by telegraph as defined in the Telegraph Acts, 1863 to 1924, without the aid of any wire connecting the points from and at which the messages or other communications are sent and received.

It will be seen that this covers telephony and broadcasting.

The Amateur's Position.

Much more serious matters are those of Section 2, which are made to *look* as if they maintain the rights of amateur experimenters, but actually give no rights at all. These are most deceptive. Take, for example, Section 2 (1) :—

> Where the applicant for a licence proves to the satisfaction of the Postmaster-General that the sole object of obtaining the licence is to enable him to conduct experiments in wireless telegraphy, a licence for that purpose shall be granted, subject to such special terms, conditions, and restrictions as the Postmaster-General may think proper, but he shall not be subject to any rent or royalty.

That looks excellent. But note "proves *to the satisfaction of the Postmaster-General.*" It is notorious that during the last year or two this "satisfaction" has been as capricious as a maiden's fancy. It has turned down serious professors, desirous of conducting scientific experiments, and admitted careless youths quite unfitted to handle apparatus ; and there are signs that it is getting less reasonable as time goes on. Justice demands either that the consideration of applications should be in the hands of an

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impartial body (say, one representative each from the G.P.O. and the R.S.G.B., with a neutral referee) or that definite qualifications should be laid down in the Bill.

Again, look at the last few words of the clause: " . . . shall not be subject to any rent or royalty."

How nice that sounds! But compare it with Section 2 (3):—

The provisions of this section and of the enactment replaced thereby, providing that a licence is not to be subject to any rent or royalty, shall not prevent, and shall be deemed never to have prevented, fees (periodical or otherwise) prescribed for the purpose being charged in respect of the grant or renewal thereof.

And it is not as if these fees were nominal. No sensible broadcast listener objects to 2s. 6d. out of his 10s. being used to defray clerical expenses; and the experimenter would not much mind the whole of his 10s. being devoted to that purpose. But, we wonder, do our readers realise that experimenters do not get their licence for 10s.? Directly an experimenter wants any reasonable facilities as to hours or power, up go his fees to £5 or more, and there is no limit to the P.M.G.'s powers in this respect.

Regulations.

But perhaps the most pernicious of all is Section 3. Under 3 (1) "The Postmaster-General may make regulations"—about practically anything he pleases to do with wireless. 3 (2) provides heavy penalties for breach of such regulations, and 3 (3) shows that the only safeguard against these regulations, which have the full force of law, is that they must be laid before Parliament for 21 days: If an address be presented by the House praying for their annulment, His Majesty in Council may annul them.

Now, these are absurd claims to autocratic power on the part of a Government department. It is quite reasonable for the Post Office to say that the science of wireless advances so rapidly that it is impossible to cater in detail for it, and that there must be the power of making regulations from time to time. But the scope of such regulations should be severely limited, and it should be laid down that they have no force until formally ratified by Parliament after proper discussion.

Section 4 gives particulars of messages which may not be sent—obscene matter, false distress signals, etc., and we have no quarrel with it, nor with 5 and 6. But 7, again, tries to encroach unreasonably. It is, however, ambiguous. The exact words are:—

The provisions of this Act shall apply to the installation and working of apparatus for utilising etheric waves for the purpose of the sending or receiving of energy without the aid of any wire connecting the points from and at which the energy is sent and received as they apply to the installation and working of apparatus for wireless telegraphy.

The difficulty is in the word "as." If it means that the Act shall apply to such apparatus, because it is like wireless apparatus, then it is not necessarily true. If it means that the Act shall apply to such apparatus as far as it is like wireless apparatus, then it goes too far. The application should be limited to cases in which such apparatus could actually be used for wireless without substantial alteration.

Section 8 deals with an "emergency," *i.e.*, war, etc. But here again the Bill goes too far. The first words read:—

"If at any time in the opinion of a Secretary of State an emergency has arisen . . ."

Thus, any sufficiently important politician could stop wireless at a few days' notice! There is nothing about the proclamation of a state of emergency as the result of full Government deliberation.

A Danger to All.

It will be obvious from what we have said that the Bill, if passed into law, will give autocratic power to a department which has not in the past shown itself considerate or helpful. The amateur will be in a much worse position than to-day.

Do not let us forget that behind the scenes there are always the Services and the big commercial companies, all of whom want the whole ether if they can get it, and who would only too willingly push the amateur experimenter right out of existence.

This Bill should be fought to a standstill, and it is up to every reader to get in touch with his M.P. and ask him to oppose it.

It may be said that our criticism is entirely destructive. This is true as far as this article is concerned; we have, in fact, formulated some quite definite constructive proposals, which have been put forward in the right quarter.

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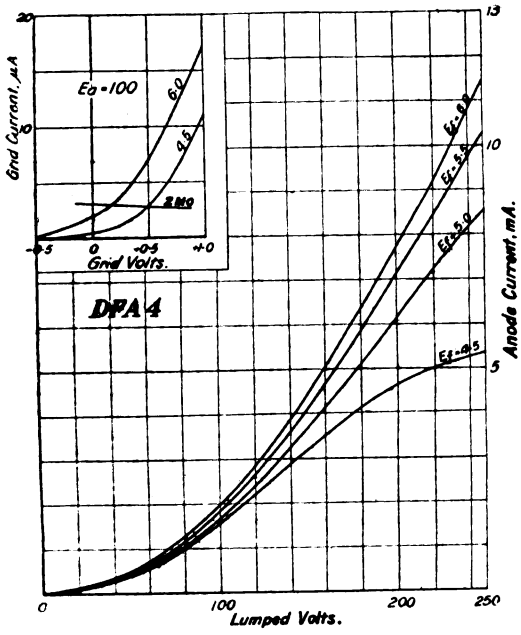
Some More New Valves.

Below we describe five more new valves—another Mullard, two Cossors, a Luminax and a Löwe Audion

The D.F.A. 4.

THIS is a valve similar to the D.F.A.1 by the same makers—a dull power valve rated at 5·5V, ·2 amp—but with a close grid for resistance amplification. Tested as usual it showed a filament current slightly below its rating. The output was



also rather below the average for valves with these filaments, being 30mA maximum instead of the usual 40. We are inclined to think that the filament of this sample had a resistance slightly above the average, and so was running cooler. The anode

Fil. Volts. E_f	Fil. Cur. I_f	Sat. Plate Cur. I_s	Anode Imped-ance. R_a	Voltage Ampli. μ	Power Ampli. P $\left(=\frac{1\,000\mu^2}{R_a}\right)$	Filament Efficiency. F $\left(=\frac{I_s}{\text{Watts.}}\right)$
4·5	·17	6	27 000	15·0	8·5	8
5·0	·18	14	21 000	14·0	9·3	15
5·5	·19	20	17 000	12·5	9·1	19
6·0	·20	30	13 000	10·5	8·5	25

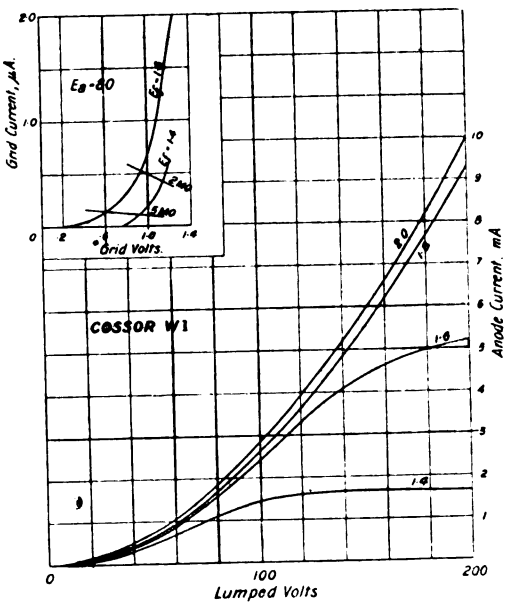
impedance varied between 27 000 and 13 000, and the μ between 15 and 10·5; our curves show the actual currents. The grid current diagram carries the line of current for a 2MO leak; it would appear that a higher leak (3MO) would be better, and that with this the valve should be an exceptionally good detector. Price 30/-

The Cossor W.1.

This is one of the two new Cossor "Wuncell" valves, and is designed as a dull emitter G.P. valve for use in place of the bright Cossor P.1 ("plain top"). It is rated at 1·8—2V

Fil. Vol.s. E_f	Fil. Cur. I_f	Sat. Plate Cur. I_s	Anode Imped-ance. R_a	Voltage Ampli. μ	Power Ampli. P $\left(=\frac{1\,000\mu^2}{R_a}\right)$	Filament Efficiency. F $\left(=\frac{I_s}{\text{Watts.}}\right)$
1·4	·27	1·8	47 000	9·8	2·0	4·7
1·6	·29	6	26 000	6·2	1·6	13
1·8	·31	—	13 500	4·0	1·3	—
2·0	·34	—	12 500	3·6	1·1	—

on the filament, and, as shown, was tested at various voltages between 1·4 and 2, the current being ·27 to ·34 amp. This puts it on the same footing as the well-known 235 type (see p. 363) although it is actually rather more economical, and differs entirely in construction, having an oxide-coated filament.



Our table shows the values of its constants at various filament heats; but we could not find all the saturation currents. On attempting to arrive at them, we simply caused as steady increase of current (at all filament heats above 1·6 volts) and found

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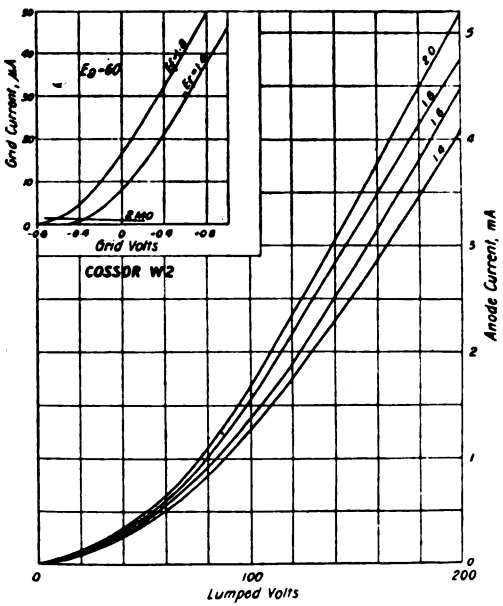
that the valve was ionising. In practice we should recommend a maximum load of 7-8mA, to avoid disintegration of the filament.

The extremely small grid current is a notable feature.

In construction, the valve has some excellent points. The cap is now without the usual metal band, and, further to reduce capacity, the moulding



is completely cut away between the legs, being in fact only a hollow, cylindrical shell. The electrode supports have been rearranged to allow for a central support to the filament.

Price: 18s.

The Cossor W.2.

This is the companion valve to the previous one, corresponding to the bright Cossor "Red-top." As will be seen from our curves and tables, the main difference is a grid of closer mesh (or heavier wire) giving a higher magnification. Otherwise it is essentially similar, except that it takes quite a large grid current at zero volts; it should make a sensitive detector with a 2-megohm leak.

Fil. Volts. E_f	Fil. Cur. I_f	Sat. Plate Cur. I_s	Anode Imped-ance. R_a	Voltage Ampli. μ	Power Ampli. P $\left(=\frac{1\,000\mu^2}{R_a}\right)$	Filament Efficiency. F $\left(=\frac{I_s}{\text{Watts.}}\right)$
1·4	·28	—	33 000	8·8	2·3	—
1·6	·31	—	30 000	8·0	2·1	—
1·8	·33	—	28 000	7·8	2·3	—
2·0	·36	—	25 000	8·3	3·7	—

It is to be noted that both the valves can be supplied in a useful modification, known as types WR1 and 2, in which there is incorporated within the cap a fixed resistance of about 8 ohms. This is cut in or out by a small milled-head screw, and when in circuit, enables the valve to be used safely with a 4 or 6-volt battery and the usual 6-ohm rheostat. In this modification, both types sell at 20s.

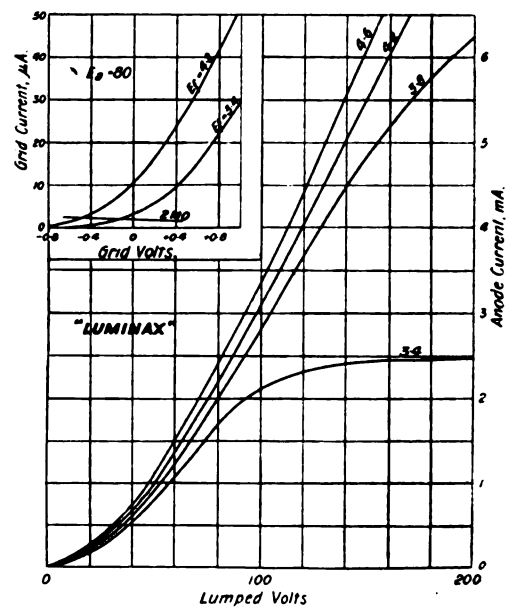
"Luminax."

This is a new British valve sold by Messrs. "Luminax" Electric Supplies, 553, Mansion House Chambers, Queen Victoria Street, E.C.4. It is in appearance a typical "R" type, with round

Fil. Volts. E_f	Fil. Cur. I_f	Sat. Plate Cur. I_s	Anode Imped-ance. R_a	Voltage Ampli. μ	Power Ampli. P $\left(=\frac{1\,000\mu^2}{R_a}\right)$	Filament Efficiency. F $\left(=\frac{I_s}{\text{Watts.}}\right)$
3·4	·66	2·4	33 000	6·6	1·3	1·1
3·8	·70	6·8	25 000	6·6	1·8	2·5
4·2	·74	17·5	18 000	6·0	2	5·7
4·6	·77	31·5	15 000	5·5	2	9·0

bulb, but it is rated to take 4—5 volts on the filament. We found on test that it would do good work with less, and at its rated voltage has enough output to handle a fair-sized loud-speaker.

Our table shows that its anode impedance is quite low, and the magnification medium; and it will be seen from the drawing that the curves are very nice and straight. These show that the valve should be a quite exceptional amplifier for this type, and it should detect quite reasonably



well. It is magnesium exhausted, and appears to be dead hard.

Altogether, a very good valve, especially in view of its low price of 8s. 6d.

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Löwe Audion.

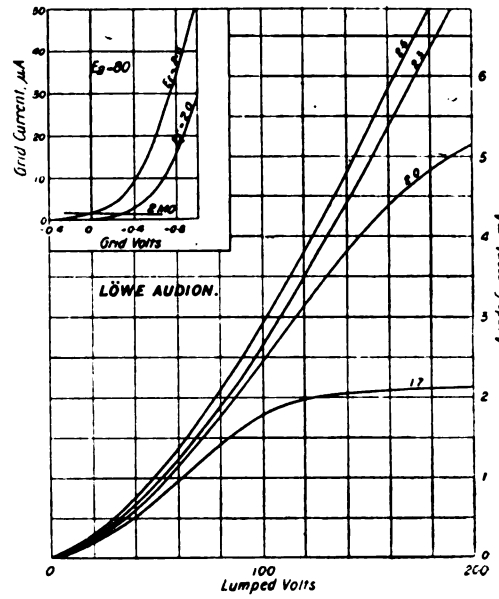
A German valve, handled in this country by Messrs. R. Stitchling, 52, Dorset Street, W.1 The one tested is a dull-emitter, rated to take ·16—·17 amp. at 2·0—2·5 volts on the filament;

Fi Volts. E_f	Fil. Cur. I_f	Sat. Plate Cur. I_s	Anode Imped-ance. R_a	Voltage Ampli. μ	Power Ampli. P $\left(=\frac{1\,000\mu^2}{R_a}\right)$	Filament Efficiency. F $\left(=\frac{I_s}{\text{Watts.}}\right)$
1·7	·15	2·1	48 000	3·3	·23	8·4
2·0	·16	6·3	28 000	3·6	·45	19·5
2·3	·17	12·6	22 000	3·0	·42	32
2·6	·18	21	21 000	2·9	·42	45

it was tested at 1·7 to 2·6 volts. It is a neat and small valve, with a bulb of the general shape of the well-known B.T.H. B5 ("306" type, see p. 363) It is magnesium exhausted.

A notable point in view of the small input—about ·4 watt—is the high saturation current, which reached no less than 21mA. Unfortunately, however, the magnification is much lower than that of the valves which are most popular in this country.

The grid current should make it a fairly successful detector, but here again it is handicapped by low μ. Price: 15s. 6d.



Some Fixed Condensers.

A number of these have been recently received for test, and details are given below.

OCTOPUS CONDENSERS.

THESE were a series of apparently Mansbridge type fixed condensers supplied by Messrs. Radio Stocks, of Radio House, Newman Street, W.1. Prices 2s. 4d. to 4s. 8d. The table below shows nominal and actual capacities:—

Nominal	Actual	Price.
·01	·005	2/4
·25	·305	3/-
·5	·45	3/4
1·0	·875	3/10
2·0	2·0	4/8

The condensers were not tested for power factor, but appeared to be normal in this respect.

EDISON BELL FIXED CONDENSERS.

These are condensers for use in radio circuits, and are of the small enclosed mica type. Two samples were sent, nominal capacities ·001 and ·002. The actual capacities were ·000 809 and .002 17. They were not tested for power factor. General design and construction appeared very good. Supplied by Messrs. J. E. Hough, Ltd., Edison Bell Works, Glengall Road, S.E.15. Price 1s. 3d.

PARAGON CURTIS CONDENSERS.

These are mica condensers for use in radio circuits and are special in construction. The makers state that they are made up very carefully with high quality mica and are then placed in moulds and sealed complete in solid bakelite under heavy pressure. They are claimed to be within 5 per cent. of rated values, and also to be entirely waterproof. It may be remembered that they were exhibited under boiling water at the White City show. We have seen test reports which show very good power factor. Reports of tests after being placed in water for some time at the N.P.L. show that the insulation remains high but the power factor increased until the condensers had dried off. Two samples were submitted, nominal capacities ·000 3 and ·001, actual capacities ·000 312 and ·001 028, the errors being within the 5 per cent. limit mentioned above. Supplied by Messrs. Peter Curtis, Ltd., 34/36, Whitfield Street, W.1. Prices range from 1s. 9d. to 3s. 6d.

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For the Esperantists.

The following, it must be understood, is not the translation of any article appearing in English elsewhere in this issue. It is an entirely independant feature specially prepared for our Esperanto-speaking readers.

Pri l'Absorbo de Ondoj Mallongaj.

Resumo de tre interesa artikolo, verkita de J Granier, kiu aperis franclingve en "L'Onde Electrique."

EKSPERIMENTOJ por determini la rezistancojn kaj dielektrikajn perdojn de diversaj substancoj ĉe oscilaj kurentoj de frekvencoj de 10^{-8} (ondlongo de 3 metroj). Tri-metra oscilatoro estas malapude kuplita al fermita oscila cirkuito enhavanta fiksan induktancon, varian kondensatoron, konatan varian rezistancon kaj indikatoron de altfrekvenca kurento.

Oni mezuras la rezistancon de konduktoro, unue enmetante la konduktoron en la cirkuiton kaj ĝuste resonancigante la cirkuiton kun la oscilatoro per la varia kondensatoro. Poste oni anstataŭigas la konduktoron mezurotan per la konata rezistanco, kiun oni alĝustigas ĝis oni obtenas la saman kurenton je resonanco kiel antaŭe. Por dielektrikoj, oni ilin enmetas anstataŭ la kondensatoro. Anstataŭigante la dielektrikon mezurotan per aera kondensatoro de malgranda perdo, kaj realĝustigante la rezistancon por doni la saman kurenton, oni alvenas je la ekvivalenta seria rezistanco, kiu egalas la dielektrikan perdon.

Estante malgrandaj, la altfrekvencaj kurentoj bezonas indikatoron pli sentivan ol la ordinara varmfadena ampermetro, kaj la instrumento fakte uzata estas interesa pro malkareco kaj inĝenieco. Oni enmetas en la altfrekvencar cirkuitor ordinaran 1-kandelpovan bulbon poŝlampan de malmulta konsumo, tiel ke ĝia filamento estas pli aŭ malpli varmigata de la altfrekvencaj, kiuj fluas tra ĝi; ĉi-tio ŝanĝas la kontinukurentan rezistancon de la bulbo, registritan ĉe Ponto Wheatstone'a kompensita por kontinua kurento, de kiu la bulbo estas unu brako. La aranĝo estas, fakte, simpla bolometra ponto.

La rezultoj de mezuroj faritaj je ĉi-supra treege alta frekvenco estas interesaj. La surfaca efiko de fero estas multe troigita pro sia trapenetrebleco, kaj ĝia histerezo provizas pluan fonton de perdo. Oni trovis, ke fera fadeno, diametre unu milimetron, havas rezistancon de 20 omoj por metro. Oni trovis, ke stanita kupra fadeno havas rezistancon 2·8-oble pligrandan ol nuda fadeno, ĉar la forta surfaca efiko fluigas la pligrandan parton de l'kurento tra la surfaca tavolo de stano kaj ne tra la korpo de la kupro. Zinkita fero estus pli bona konduktoro ol stanita kupro, ĉar zinko estas pli bona konduktoro ol stano.

La kondukiveco de fadeno mergita en elektrolitoj diversfortaj, montris interesajn efikojn. Kiam la fadeno estis ĉirkaŭita de elektrolito nur iomete kondukiva, la plej multan parton de la kurento portis la fadeno. Dum oni pliigis la kondukivecon de l'elektrolito, pli granda proporcio de la kurento vojaĝis pere de l'elektrolito, dum la neta rezistanco de la sistemo pliiĝis.

Ekzemple, fadeno kun longo 3 c.m. kaj diametro 0.1 c.m., mergite en sulfatacido 0·9-procenta, montris rezistancon de 2·2 omoj, sed mergite en sulfatacido 20-procenta, montris rezistancon de 4·8 omoj.

La potencan faktoron de akvo kiel dielektriko en kondensatoro oni mezuris uzante distilitan akvon, riveran akvon, kaj maran akvon, respektive. Ĉe la lasta, la funkcipovo de l'kondensatoro ĉesis rilate al la agordita cirkuito. Oni ankaŭ faris mezurojn de potenca faktoro de nombro da ordinaraj dielektrikoj, kaj kvankam oni ne pretendas, ke la ciferoj ricevitaj estas absolute ĝustaj oni povis aranĝi nombron de tiuj substancoj laŭ klara ordo de merito. Parafino kaj glimo facile estas la plej bonaj, sekvataj de seka briko kaj seka tero. Sekvas vitro kaj vaksita papero, dum sub ili en la listo ebonito egalas ordinaran brikon! Humidaj objektoj, ekz., folioj kaj neseka tero, estas la plej malbonaj dielektrikoj.

La aŭtoro de l'artikolo diskutas la eblan rilaton de siaj observadoj ĉe treege mallongonda sendado, kaj klarigas la seriozan efikon pro ĉeesto de malbonaj dielektrikoj en mallongonda aparato.

Listo de Mallongigoj uzataj por Radio-Telegrafia Sendado.

List of Abbreviations used in Radiotelegraphic Transmission.

Eltirita el la Internacia Radiotelegrafia Kunveno.

Mallongigo.	Demando.	Respondo aŭ Informo.
— . — . — — . —	(CQ)	Demanda signalo uzata de stacio, kiu deziras korespondi. *Inquiry signal employed by a station which desires to correspond.*

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Mallongigo.	Demando.	Respondo aŭ Informo.
—.—.(TR)		Signalo anoncanta la sendon de indikoj pri ŝipstacio. *Signal announcing the sending of indications concerning a ship station.*
— — . . — — (!)		Signalo indikanta, ke stacio estas sendonta grandpotence. *Signal indicating that a station is about to send with high power.*
PRB	Ĉu vi deziras komuniki kun mia stacio per la Internacia Signala Kodo ? *Do you wish to communicate with my station by means of the International Signal Code ?*	Mi deziras komuniki kun via stacio per la Internacia Signala Kodo. *I wish to communicate with your station by means of the International Signal Code.*
QRA	Kio estas la nomo de via stacio ? *What is the name of your station ?*	Tiu-ĉi stacio estas..... *This station is.....*
QRB	Kiom malproksime vi estas de mia stacio ? *How far are you from my station ?*	La distanco inter niaj stacioj estas.....maraj mejloj. *The distance between our stations is.....nautical miles.*
QRC	Kio estas via ĝusta biro ? *What are your true bearings ?*	Mia ĝusta biro estas.....gradoj. *My true bearings are.....degrees.*
QRD	Kien vi celas ? *Where are you bound ?*	Mi celas..... *I am bound for.....*
QRF	De kie vi venas ? *Where are you coming from ?*	Mi venas de..... *I am coming from.....*
QRG	Al kiu kompanio aŭ linio de navigacio vi apartenas ? *To what company or line of navigation do you belong ?*	Mi apartenas al..... *I belong to.....*
QRH	Kio estas via ondlongo ? *What is your wave-length ?*	Mia ondlongo estas.....metroj. *My wave-length is.....metres.*
QRJ	Kiom da vortoj vi havas por sendi ? *How many words have you to transmit ?*	Mi havas.....vortojn por sendi. *I have.....words to transmit.*
QRK	Kiel vi ricevas ? *How are you receiving ?*	Mi ricevas bone. *I am receiving well.*
QRL	Ĉu vi ricevas malbone ? Ĉu mi sendu 20-foje . . . — . por ke vi povu alĝustigi vian aparaton ? *Are you receiving badly ? Shall I transmit 20 times . . . — . so that you can adjust your apparatus ?*	Mi ricevas malbone. Sendu 20-foje . . . — . por ke mi povu alĝustigi mian aparaton. *I am receiving badly. Transmit 20 times . . . — . so that I can adjust my apparatus.*
QRM	Ĉu vi estas ĝenata ? *Are you disturbed ?*	Mi estas ĝenata. *I am disturbed.*
QRN	Ĉu la atmosferaĵoj estas tre fortaj ? *Are the atmospherics very strong ?*	La atmosferaĵoj estas tre fortaj. *The atmospherics are very strong.*
QRO	Ĉu mi pligrandigu mian potencon ? *Shall I increase my power ?*	Pligrandigu vian potencon. *Increase your power.*
QRP	Ĉu mi malpligrandigu mian potencon ? *Shall I decrease my power ?*	Malpligrandigu vian potencon. *Decrease your power.*
QRQ	Ĉu mi sendu pli rapide ? *Shall I transmit faster ?*	Sendu pli rapide. *Transmit faster.*
QRS	Ĉu mi sendu pli malrapide ? *Shall I transmit more slowly ?*	Sendu pli malrapide. *Transmit more slowly.*
QRT	Ĉu mi ĉesigu sendadon ? *Shall I stop transmitting ?*	Ĉesigu sendadon. Mi havas nenion por sendi. *Stop transmitting.* *I have nothing to transmit.*
QRU	.. ..	Mi havas nenion por vi. *I have nothing for you.*

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Mallongigo.	Demando.	Respondo aŭ Informo.
QRV	Ĉu vi estas preta ? *Are you ready ?*	Mi estas preta. Ĉio bonorde. *I am ready. All is in order.*
QRW	Ĉu vi estas okupata ? *Are you busy ?*	Mi estas okupata kun alia stacio (aŭ kun.....), bonvolu ne interrompi. *I am busy with another station (or with.....), please do not interrupt.*
QRX	Ĉu mi atendu ? *Shall I wait ?*	Atendu. Mi vokos vin je.....a horo (aŭ kiam mi bezonos vin). *Wait. I will call you at.....o'clock (or when I want you).*
QRY	Kiu estas mia vico ? *What is my turn ?*	Via vico estas No..... *Your turn is No.....*
QRZ	Ĉu miaj signaloj estas malfortaj? *Are my signals weak ?*	Viaj signaloj estas malfortaj. *Your signals are weak.*
QSA	Ĉu miaj signaloj estas fortaj ? *Are my signals strong ?*	Viaj signaloj estas fortaj. *Your signals are strong.*
QSB	Ĉu mia tono estas malbona ? *Is my tone bad ?*	La tono estas malbona. *The tone is bad.*
	Ĉu mia sparko estas malbona ? *Is my spark bad ?*	La sparko estas malbona. *The spark is bad.*
QSC	Ĉu la interspacado estas malbona ? *Is the spacing bad ?*	La interspacado estas malbona. *The spacing is bad.*
QSD	Ni komparu poŝhorloĝojn. Mia horo estas..... Kiom via horo ? *Let us compare watches. My time is..... What is your time ?*	La horo estas..... *The time is.....*
QSF	Ĉu la radio-telegramoj estos sendataj alterne aŭ serie ? *Will the radiotelegrams be transmitted alternately or in series ?*	La sendado estos alterna. *The transmission will be in alternate order.*
QSG	.. ..	La sendado estos laŭ serio de kvin radio-telegramoj. *Transmission will be in series of five radiotelegrams.*
QSH	.. ..	La sendado estos laŭ serio de dek radio-telegramoj. *Transmission will be in series of ten radiotelegrams.*
QSJ	Kiom la prezo kolektota por..... ? *What is the charge to collect for..... ?*	La prezo kolektota estas..... *The charge to collect is.....*
QSK	Ĉu la lasta radio-telegramo estas nuligita ? *Is the last radiotelegram cancelled ?*	La lasta radio-telegramo estas nuligita. *The last radiotelegram is cancelled.*
QSL	Ĉu vi havas la ricevateston ? *Have you got the receipt ?*	Bonvolu doni ricevateston. *Please give a receipt.*
QSM	Kio estas via ĝusta direkto ? *What is your true course ?*	Mia ĝusta direkto estas..... gradoj. *My true course is.....degrees.*
QSN	Ĉu vi komunikas kun la tero ? *Are you communicating with land ?*	Mi ne komunikas kun la tero. *I am not communicating with land.*
QSO	Ĉu vi komunikas kun alia stacio (aŭ kun.....) ? *Are you in communication with another station (or with.....) ?*	Mi komunikas kun.....(pere de.....). *I am in communication with..... (through the medium of.....).*
QSP	Ĉu mi signalu al..... ke vi vokas lin ? *Shall I signal to.....that you are calling him ?*	Informu al....., ke mi vokas lin. *Inform.....that I am calling him.*
QSQ	Ĉu mi estas vokata de..... ? *Am I being called by..... ?*	Vi estas vokata de..... *You are being called by.....*
QSR	Ĉu vi forsendos la radio-telegramon ? *Will you despatch the radio-telegram ?*	Mi forsendos la radio-telegramon. *I will forward the radiotelegram.*
QST	Ĉu vi ricevis ĝeneralan vokon ? *Have you received a general call ?*	Ĝenerala voko al ĉiuj stacioj. *General call to all stations.*

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Mallongigo.	Demando	Respondo aŭ Informo.
QSU	Bonvolu voki min, kiam vi estos fininta (aŭ je.....a horo). *Please call me when you have finished (or at.....o'clock).*	Mi vokos vin, kiam mi estos fininta. *I will call you when I have finished.*
QSV	Ĉu okazas publika korespondado ? *Is public correspondence engaged ?*	Okazas publika korespondado. Volu ne interrompi. *Public correspondence is engaged. Please do not interrupt.*
QSW	Ĉu mi pliigu mian spark-frekvencon ? *May I increase the frequency of my spark ?*	Pliigu vian spark-frekvencon. *Increase the frequency of your spark.*
QSX	Ĉu mi devas malpliigi mian spark-frekvencon ? *Must I diminish the frequency of my spark ?*	Malpliigu vian spark-frekvencon. *Diminish the frequency of your spark.*
QSY	Ĉu mi sendu je ondlongo de.....metroj ? *Shall I transmit with a wave-length of..... metres ?*	Ni transigu al ondlongo de.....metroj. *Let us transfer to the wave-length of.....metres.*
QSZ	.. ..	Sendu ĉiun vorton dufoje. Mi malfacile ricevas viajn signalojn. *Transmit each word twice. I have difficulty in receiving your signals.*
QTA	.. ..	Sendu ĉiun radio-telegramon dufoje. Mi malfacile legas viajn signalojn, aŭ *Transmit each radiotelegram twice. I have difficulty in reading your signals, or* Ripetu la radio-telegramon, kiun vi ĵus sendis. Ricevo duba. *Repeat the radiotelegram you have just sent. Reception doubtful.*
QTB	.. ..	Nombro da vortoj ne konsentita; mi ripetos unuan literon de ĉiu vorto kaj unuan ciferon de ĉiu grupo. *Number of words not agreed; I will repeat first letter of each word and first figure of each group.*
QTC	Ĉu vi havas ion por sendi ? *Have you anything to transmit ?*	Mi havas ion por sendi. Mi havas unu (aŭ kelkajn) radiotelegramojn por.... *I have something to transmit.* *I have one (or several) radiotelegram for.....*

Kiam demandsigno sekvas mallongigon, ĝi aludas al la demando indikita rilate al tiu mallongigo.

Ekzemplaro.

Stacio.		
A	QRA ?	Kio estas la nomo de via stacio ?
B	QRA Rimutaka.	Ni estas la Rimutaka.
A	QRG ?	Al kiu kompanio aŭ linio de navigacio vi apartenas ?
B	QRG Linio New Zealand QRZ.	Mi apartenas al la Linio New Zealand. Viaj signaloj estas malfortaj.

La stacio A tiam pliigas la potencon de sia sendilo, kaj sendas :—

A	QRK ?	Kiel vi ricevas ?
B	QRK.	Mi ricevas bone.
	QRB 100.	La distanco inter niaj stacioj estas 100 maraj mejloj.
	QRC 70.	Mia ĝusta biro estas 70 gradoj.

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Letters of interest to experimenters are always welcome. In publishing such communications the Editors do not necessarily endorse any technical or general statements which they may contain.

Valve and Valve Holder Measurements.

The Editor, E.W. & W.E.

DEAR SIR,—May I be allowed to offer you my hearty congratulations, and to express the hope that future issues of E.W. & W.E. will prove as interesting as those of the past?

With reference to the articles in recent issues on the Inter-Electrode Capacities of Valves I have made some measurements on valves and valve-holders myself and I venture to hope that the results, which I enclose, will be of interest.

The method of testing used is as follows: An oscillating valve circuit is set up and tuned by means of a calibrated variable condenser of maximum capacity, 0.0001 mfd. The valve-holder to be tested is connected in parallel with the variable condenser. Another oscillating circuit is now coupled to the first one and adjusted by heretodyning to oscillate at the same frequency.

The valve-holder under test is now disconnected from the circuit, the wires forming the connections being left in position. By varying the capacity of the calibrated condenser the circuit is readjusted to the original frequency. The increase of capacity of the calibrated condenser required to do this is the capacity of the valve-holder previously removed from the circuit. These tests were made on a wave-length of about 300 metres.

Brighton. W. G. WHITE.

Anode to Filament (1)		5·5mmF.	Valve holder mounted on wood block for laboratory work.
A	„ F (2)	5·5	
A	„ F_1 & F_2 joined	9	
Grid	„ F_1	6	
G	„ F_2	6	
G	„ F_1 & F_2 joined	10	
A	„ G_1	5	
A	„ F_1 F_2 joined	3	Valve-holder of standard design.
G	„ F_1 F_2 „	4	
A	„ G	3	
A	„ F_1 F_2 joined by filament	7	
G	„ F_1 F_2	7·5	Mullard Ora valve after allowing for holder.
A	„ G_1	3	
A	„ F_1 F_2 joined by filament	8·5	
G	„ F_1 F_2	8	Marconi-Osram R.5.
A	„ G	4	
A	„ F_1 F_2 joined by filament	8·5	
G	„ F_1 F_2	8·5	Ediswan 5·5V.
A	„ F_1 F_2 joined by filament	8	
G	„ F_1 F_2	7·5	Marconi-Osram R.A.
A	„ G	3	
A	„ F_1 F_2 joined	4	V.24.
G	„ F_1 F_2	4	Valve-holder.
A	„ G	2	

The Editor, E.W. & W.E.

DEAR SIR,—Having only just discovered your most interesting periodical, E. W. & W. E. I have perused the first number which has come into my possession (January) with care, and among the many articles which attracted my attention was that by Mr. Barton Chapple concerning the inter-electrode capacities of valves. The principal reason for my special interest in this article is the fact that about a year ago I went to considerable trouble to make a series of similar measurements. I am surprised to find, however, that there are considerable differences between my results and those of Mr. Barton Chapple, and on repeating one or two of my own measurements, I got results so closely agreeing with my previous ones that I did not repeat the whole series.

My method was to use two oscillating valves heterodyning one another, one having a grid condenser and leak, and having telephones in the anode circuit. One of the tuning condensers had shunted across it a special vernier consisting of two concentric tubes, the inner one sliding and fitted with a scale. Now, the capacity of such a condenser, or, rather, the *difference in capacity between two settings*, can be very accurately calculated from the formula:—

$$K = \frac{L}{4\,145\,400 \log_{10} \frac{R_1}{R_2}}$$

Where K = capacity in microfarads
L = length of overlap of tubes
R_1 = inside diameter of outer tube
R^2 = outside diameter of inner tube
} in centimetres.

[NOTE: The absolute capacity of any given setting cannot be calculated because of the "fringe" effect.]

The two oscillating circuits were so tuned with respect to one another as to produce an audible

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beat note in the telephones of a pitch fixed by a tuning fork, the tubular vernier being set at a convenient reading near its maximum capacity.

The capacity to be measured was then shunted across this vernier, and the movement necessary to restore the beat note to its original pitch is a direct measure of the capacity.

The accuracy of this method of measurement is very great indeed provided that the obvious precautions are taken, and I found that results were reproducable to within about 0·1 micromicrofarad.

My figures, which are rather more complete than Mr. Barton Chapple's, are as follows:

	A-G	G-F	A-F
Complete Valves—			
Marconi 4V.R.	3·5	4·2	3·9
Ediswan AR (Bright) ..	3·1	5·4	4·1
Cossor P.1	4·0	5·2	4·2
Mullard Ora (Bright) ..	2·5	3·6	3·8
Extraudion	5·4	5·5	4·8
Standard valve base and pins ..	1·1	1·6	1·4
Marconi 4V.R., electrode only, specially mounted for measurement	2·0	1·1	0·8
Standard valve holder	2·9	8·2	6·9

[These figures are in micromicrofarads.]

In all cases G-F and A-F were measured with the two filament pins connected together.

Points of special interest in the above table are, firstly: The large relative value of the figures for the standard valve-holder (the ordinary type where the valve sockets are embedded in a moulded block), but it must be remembered that these figures would depend to a great extent on the outside diameter of these sockets (in this case ·25 inches); secondly: If we consider the two sets of figures relating to the Marconi valve, together with those for a standard four-pin base, we find that, for A-G, for instance,

$$3{\cdot}5 - (2{\cdot}0 + 1{\cdot}1) = 0{\cdot}4,$$

which figure must represent the whole capacity due to the internal connections, including the much-maligned "pinch"—apparently not such a serious item as is generally supposed.

I made no measurements on the V.24 holder, but examination of one of these, or even of Mr. Barton Chapple's own diagram, is surely sufficient to cast grave suspicion on his figures. Considering the relative position of the contact springs, is it not very remarkable that the figures should all be so nearly the same? And is it not also remarkable, considering the end for which the holder was specially designed, that it is apparently very little better than the old-fashioned article (again according to Mr. Barton Chapple's figures)?

Some of the discrepancies seem to suggest a missing decimal point—not in my figures because the scale of my vernier, which I have marked to read directly in micromicrofarads, agrees with the scale on a calibrated ·005 condenser which I was using at the same time.

Now to a quite different subject.

The article on aerials by Dr. Smith-Rose and Mr. Colebrook interested me greatly, and I was pleased to read of many moot points definitely settled. I think, however, that the experiments might have been made complete by investigating the properties of the **T** aerial.

This type of aerial possesses advantages for short wave work, and, moreover, is in some environments the only type which can be used without considerable sacrifice of length.

I am thinking more particularly of the much-discussed question as to the position of the junction to the down lead. The laws which govern this question with regard to the aerial might be expected to apply in some degree at least to the counterpoise, and yet I notice that the authors took the connection to the counterpoise neither at its end nor at its centre. Was this a mere haphazard arrangement, or was there any good reason other than convenience in making connection to the set?

P. G. DAVIDSON.

Avon Leys,
Stratford-on-Avon.

Change of Address.

The Editor, E.W. & W.E.

DEAR SIR,—I beg to inform you that I have now removed my experimental radio station, 2SP, to the address below, and should esteem it a favour if you would insert the change in E.W. & W.E.

R. MANSFIELD,
A.M.Inst. R.E.

27, Rutland Road,
Southport, Lancs.

Call Signs.

The Editor, E.W. & W.E.

DEAR SIR,—The Call Sign 2II (two i i) which formerly belonged to the Southport Wireless Society of Southport, has now been allocated to me; and as I believe that reports are still being addressed to Southport, I should be very much obliged if you will give the correct address in a future issue of your paper. The wave-lengths in use are 115-130 metres and 200-440 metres.

A. M. RALLI.

14, Torrington Road,
Wallasey,
Cheshire.

The Editor, E.W. & W.E.

DEAR SIR,—We beg to submit our radio call sign, 2GY, which was previously held by a London amateur. We shall welcome any reports on our transmissions.

F. C. HARDWELL & SON,

91A, Temple Street,
Bristol.

2ABR.

The Editor, E.W. & W.E.

Please note that above call sign was allocated to me 3/10/24. Ten watts.

ALAN SMITH.

48, High Street,
Yewsley, Middlesex.

More for Beginners.

The Editor, E.W. & W.E.

DEAR SIR,—May I express my endorsement of "Beginner's" letter which appeared in your February issue? In that letter he expresses exactly what I have thought myself, but he does it far better than I could have done. Particularly

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do I agree with his statement that "Text-books . . . . do not show us how to allow for the errors, etc."; and I think many amateurs would be grateful if you would indicate the precautions necessary with various instruments, and in various measurements, to ensure the results obtained being accurate.

In addition, may I ask if it would be possible for you to run an "Experiments" section, in which you would indicate experiments which might be undertaken on subjects about which little data is available, together with a brief statement of the procedure which might be adopted and the precautions necessary?

For example, I have not yet seen any details published of the effect of the spacing of the turns of an inductance coil, or the effect of using very thick wire, etc. I have seen general statements, but not quantitive measurements showing the benefits, or otherwise, that would result.

I would like to undertake some such measurements myself, but do not feel competent. With your suggestions on the lines indicated, I would approach the problem with much more confidence.

Such a section would also be of very great value to "Wireless Societies" that wish to rise above "circuit testing" but lack the necessary "professor."

In the January issue, on page 201, speaking of the Moullin voltmeter, you say that the grid condenser and leak type has the disadvantage of putting a measurable load on the circuit. Moullin, in his original article, appears to me to show that it is such a small amount as to be entirely negligible. Perhaps you will be good enough to show, when practicable, how to calculate the power consumed by this type?

In conclusion, may I congratulate you on the excellence of E.W. & W.E. "Every month in every way it gets better and better."

JAS. HUDSON.

Hulme, Manchester.

A Plea for Better Keying.

The Editor, E.W. & W.E.

DEAR SIR,—May I, through the medium of your correspondence columns, make an appeal for better "fists" on the air?

It is really surprising how many of our best-known transmitters are indifferent performers upon the key, and I am sure that such measure of success as they have achieved would be considerably increased if they would pay more attention to this.

In the first place, indifferent sending would seem to arise from a general tendency to key too fast, and this is particularly in evidence when calling and signing off—just when the most careful and deliberate keying is needed. Greater care in this matter would certainly result in a greater number of reports.

There are, of course, exceptions to whom the above remarks do not apply, and it is refreshing to tune such a sender as G2OD after guessing at some of the others.

It has been remarked that G2OD "gets there" time after time, while others, whose signals seem stronger, are less successful, and I believe that his remarkable successes are due in the first place to his correct and deliberate keying, and secondly to his perfectly pure C.W. note, which is undoubtedly made penetrating through QRM and QRN than raw A.C. or imperfectly smoothed D.C.

G2OD does not send fast. I doubt if he ever exceeds 12 to 15 w.p.m. At any rate, when working DX, and our own experience of listening to DX stations certainly indicates the advantage of such methods.

In order to disarm possible criticism I will admit that I am not a fast reader, although I would far sooner copy a good fist at 20 w.p.m. than an indifferent one at 15, and I think this is a common experience, but the point is that there appears to be few amateur operators whose style at even 12 w.p.m. is passably correct. It must be remembered that the majority of amateurs have "picked up" their keying. They have not had the advantage of practice at a telegraph school, under supervision of a qualified instructor, and this is why the professional operator's keying at 30 w.p.m. is superior to the amateur's at 20 or less.

In conclusion, then, may I urge transmitters who have not been trained in keying to listen to G2OD or U2XI for example, and then go and do likewise.

Let us make the GS conspicuous for their good style and correctness on the air.

HUGH J. B. HAMPSON (G6JV).

Johannesburg Reception.

The Editor, E.W. & W.E.

DEAR SIR,—Perhaps you may be able to find room for the following short "par." in connection with my article in the January issue of E.W. & W.E. The small error on the part of your draughtsman was quite excusable, but I should like to see the matter corrected.

VICTOR HART.

Johannesburg.

["In the diagram accompanying the article, 'Remarkable Reception of KDKA in Johannesburg,' published on page 239 of the January issue, an error of wording can be noted. The first anode coil, at top left of diagram, was marked as having 4½ turns; this must be corrected and should read 9½ turns."]

Reports Wanted.

The Editor, E.W. & W.E.

DEAR SIR,—Can you find space in an odd corner in E.W. & W.E. to say that 2RA would be pleased to receive reports of low power transmissions from any amateur, British or foreign, who may hear me working?

My call is not in any of the published lists, as I have used the radiating aerial only when absolutely necessary and up to the present have not been in need of reports from outside.

With all good wishes for the prosperity of E.W. & W.E., which is, in my opinion, the only paper for the transmitting amateur.

FREDK. F. WARNER.

Radio 2RA,
Northdene, High Lane,
Nr. Stockport.

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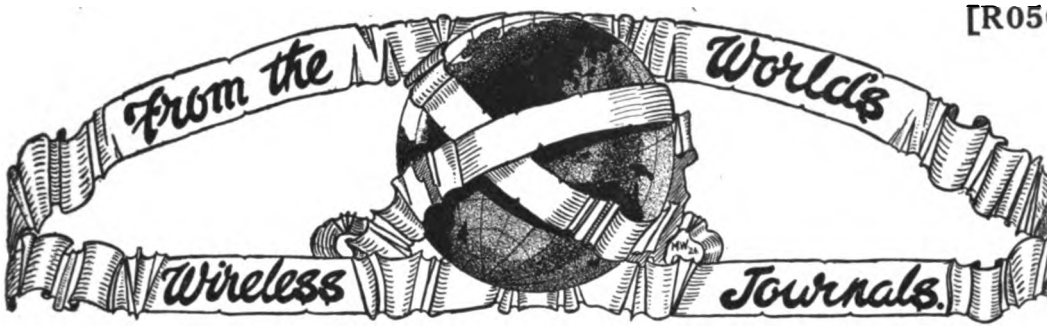
[R050



R100.—GENERAL PRINCIPLES AND THEORY.

R113·8.—WIRELESS AND THE ECLIPSE. *Electn.*, Feb. 6, 1925).

Some curves are given showing the results of observations on wireless signals during the eclipse of January 24, 1925. The signal intensity measured at a receiver in Somerset of the signals from a transmitter at Rocky Point, Long Island, U.S.A., showed an abnormal increase during the eclipse followed by an abnormal decrease. Observations made at Slough on the effect of the eclipse on signal bearings yielded negative results.

R200.—MEASUREMENTS AND STANDARDS.

R220. — UBER KAPAZITÄTEN IN ELEKTRONENRÖHREN.—E. Schrader (*Jahrb. d. drahtl Tel.* Vol. 24, No. 2).

Details of theoretical and practical research on the inter-electrode capacities of valves. The subject is treated with special reference to effective capacities at high frequencies. Since work of this kind involves the measurement of very small capacities (of the order of a few centimetres or $\mu\mu$F) very delicate methods are necessary, the one used in this case being of particular interest. The measuring circuit consists of an isolated resonant circuit comprising an inductance shunted by two variable condensers, in parallel, one of these condensers being calibrated and providing fine adjustment of tuning. Essentially the procedure is to tune this circuit to a certain frequency, to shunt the capacity under measurement across the existing condensers, and then to bring the circuit back to its original resonance by varying the fine condenser. The method by which this resonance is indicated is the interesting feature. Loosely coupled to the measuring circuit are a valve oscillator and an oscillating detector, the latter being connected to a telephone receiver. These two oscillators are adjusted to give an audible heterodyne note in the telephone receiver. Now if the measuring circuit is varied by turning one of its condensers so that it passes through resonance with, say, the oscillating detector, the pitch of the heterodyne note will vary in the neighbourhood of the resonant point, rising above normal just below the resonant point and falling below normal just above it.* Hence by specifying a definite heterodyne pitch in the immediate vicinity of the resonant point one also fixes a definite resonant frequency in the measuring circuit. This pitch is fixed by a third oscillator generating at a fixed audio-frequency which forms low period beats with the heterodyne note in the telephone receiver. The two audible frequencies may be brought so close together as to form only about one beat per second or even less. In this way the resonant frequency of the measuring circuit may be always brought back to the same value with a high degree of precision. So sensitive is the method to capacity effects from the body that it may be necessary to make condenser dial readings with the aid of a telescope. The valve capacities are measured under working conditions and the dependence of effective capacity upon the external loading of the anode circuit are investigated. The results are compared with the work of H. G. Möller and J. M. Miller, an agreement being found at low frequencies but serious deviations from the theory being found at high frequencies. In measuring the capacity of a valve the A.C. voltage applied to the grid must be sufficiently small to make the valve operate on a linear portion of its characteristic. The space-charge in a valve may alter the capacity of the valve by about 3 cms. The capacities C_{ga}, C_{gf} and C_{af} are not the values given by inclusion in the measuring circuit and a method is given of arriving at the true values for these capacities.

R220·333.—THE INTER-ELECTRODE CAPACITIES OF THERMIONIC VALVES.—L. Hartshorn, B.Sc. and T. I. Jones, B.Sc. (*Exp. W.*, Feb., 1925).

This paper deals with important questions of the capacities between the electrodes of thermionic valves and gives details of a series of experiments which were made to determine the value of these capacities in normal types of valve. The contributions to the total capacity of an R valve due to the electrodes themselves, the leads through the pinch, the pins and the valve-socket respectively were determined.

R223·240. — R. F. PROPERTIES OF INSULATING MATERIALS.—J. L. Preston and E. L. Hall (*Q.S.T.*, Feb., 1925).

Some measurements made by the Bureau of Standards on the dielectric properties of a number of common insulating substances. The frequency at which the measurements were made is not specified further than by stating it to be "average radio-frequency." The results are given in a table showing the dielectric constants and power

* See p. 348.

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factors as expressed by phase angles in degrees. It appears that most woods are quite good when carefully dried or boiled in paraffin or ceresin. As received from the timber dealer, however, wood may show a large phase angle. Good mica has easily the lowest phase angle (·04° as against ·5° for most glasses). Asbestos and asbestos compositions show up particularly badly. For further information the reader is referred to the article itself.* It is surprising to see that no results are included for ebonite or bakelite.

R240.—THE EFFECT OF OXIDATION ON THE HIGH-FREQUENCY RESISTANCE OF AERIAL WIRES. —L. B. Turner, M.A. (*Journ. Inst. E.E.*, Jan., 1925).

By two different methods the high-frequency resistance of hard-drawn copper wire and stranded phosphor bronze wire when bright and when oxidised was measured over a range of wave-lengths varying from 4 to 20 kilometres. The results indicate no increase in resistance whatever due to oxidation even when the surface of the wire is wet. The oxide film referred to is that which is produced by weathering. A note is added on the measuring of the H.F. resistance of thick wires.

R270.—ESSAIS ENTRE PARIS ET ALGER SUR ONDES DE 180, 90 ET 50 MÈTRES.—A. Colmant (8AG) (*Onde Elec.*, Jan., 1925).

Some experiments made during 1924 are described which were carried out with the object of ascertaining the possibility of reliable radio communication on short wave-lengths and with a power of about 100 watts between Paris and Algiers. Signals sent out regularly from a transmitting station at Paris were observed at a receiver at Algiers. The aerial used at the transmitter was a 4-wire flat-top, 23 metres high, with a fundamental wave-length of 200 metres and pointing E. and W. A valve transmitter was used, the filaments being heated with A.C. at 53 cycles and the plate current being obtained by synchronous rectification and filtering. On 180 metres, with a power of 65 watts input, signals were received very loudly at night in Algiers. There was no trace of fading and signals were still easily readable when the power was reduced to 25 watts. In the daytime no results were obtained even with a power of 225 watts. When the wave-length was reduced to 90 metres the signals at night-time in Algiers were stronger than ever, but still no daylight signals could be heard there even with a power of 380 watts. At other stations in France and England, however, the 90-metre signals were frequently heard as well by day as by night. Next the 50-metre wave-length was tried, the oscillatory circuit used at the transmitter being of the Mesny double type. The aerial was worked on a harmonic. The reception at Algiers on this wave-length was apparently less constant. Sometimes the signals were very strong but with sudden short fading. Even on 50 metres and with a power input of 125 watts the transmitter only seems to have made itself properly heard at Algiers during the day on one occasion. More frequent, but still very occasional, daylight receptions were reported from La Réole. Night reception at Algiers was always reported as favourable from November 30 to December 12, whereas reception had been erratic during the summer.

* See p. 325.

R275.—MESURE DES TAUX DE MODULATION ET COMPARISON DES INTENSITÉS DE RÉCEPTION AU MOYEN D'UN NOUVEL OSCILLOGRAPHE ELECTROMAGNETIQUE. — Raymond Dubois, Ing.E.P.C.I. (*Onde Elec.*, Jan., 1925).

Description of a method of measuring the extent of modulation in received wireless signals. The signals are first brought up to suitable detecting strength by means of H.F. amplification without reaction. They are detected by means of a crystal detector in series with the grid of a three electrode valve and the rectified component is magnified by means of a D.C. resistance amplifier. This reproduces at the output not only the A.C. modulation component but also the D.C. component due to the carrier wave. The output is directly connected to the control windings of a special type of audio-frequency oscillograph designed by the writer. By means of a beam of light controlled by the oscillograph, photographic records are obtained on a moving strip. Some oscillograms thus obtained are reproduced in the article.

R300.—APPARATUS AND EQUIPMENT.

R343.—THE MCCAA ANTI-STATIC DEVICES. PART I. (*Q.S.T.*, Feb., 1925).

Description of a system developed by Dr. G. McCaa for reducing the ratio of parasitic influences to a tuned C.W. signal in a receiver. A loose-coupled receiver is employed, the aerial inductance being divided into two parts coupled in opposite senses to the secondary circuit so that normally both signal and parasitic currents are cancelled in the receiver. Across one of the parts of the aerial inductance is shunted another relatively high inductance which normally does not upset the balance of the system, this inductance being coupled to a local oscillator. The effect of the latter is to cause large periodic variations of the shunt inductance, which has the effect of throwing the aerial coupling system alternately in and out of balance. This favours the transference of undamped signals from aerial to closed circuit to a greater extent than that of atmospherics. Modified circuits employing the same general principle are also described. Exactly why the system is effective is not quite clear to us at present, but it is stated that in practice it limits the parasitic amplitudes to that of the received signal and impresses the operator with feeling that the reduction of interference is really much greater than this. The frequency of the local oscillator is not specified, nor is the loss in signal strength consequent upon the increased selectivity.

R800.—NON-RADIO SUBJECTS.

R800.—STUDIES OF ELECTRIC DISCHARGES IN GASES AT LOW PRESSURES. PART V.—Irving Langmuir and H. Mott-Smith, Jr. (*Gen. El. Rev.*, Dec., 1924).

This article continues a series of earlier ones on the use of spherical collectors to determine the characteristics of electrical discharges in gases at low pressures, presenting additional experimental data relative to this form of electrode and entering on a dissertation on the effects of magnetic fields upon the discharges. Starting from the equations of Townsend for the mobility of ions in a magnetic field, a theory of these effects is developed, experimental results are recorded and a comparison made.

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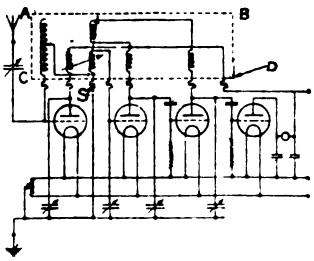
(The following notes are based on information supplied by Mr. Eric Potter, Patent Agent, Lonsdale Chambers, 27, Chancery Lane, W.C.2.)

[R008

AMPLIFIER CONSTRUCTION.

(Application date, June 9, 1923. No. 220,745.)

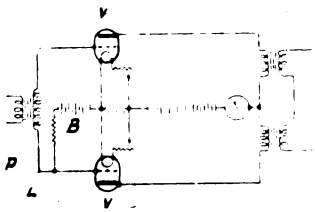
The accompanying illustration shows a form of amplifier construction for which a patent has been granted to W. J. Brown and Metropolitan-Vickers Electrical Co., Ltd. The invention really lies in providing all the inductances used in a radio-frequency amplifier in one box or compartment which is sealed up, and so constructing it that it can be interchanged. Some suitable form of spring clips, shown as S in the illustration, are used for this purpose and the special compartment is outlined at A B C D. The invention also provides for a fixed magnetic reaction coil which is rendered operative electrostatically. The first claim of the patent is exceedingly broad and covers the use of a separate removable compartment containing all the high frequency coils. We were under the impression that we had seen a device of this nature several years ago, but, of course, we are open to correction.



A PUSH-PULL AMPLIFIER.

(Application date, July 17, 1923. No. 222,981.)

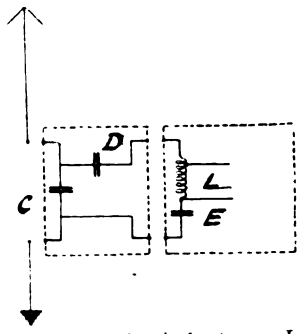
An interesting push-pull amplification scheme is described by P. G. A. H. Voigt in the above British Patent, in which the familiar differential input transformer is eliminated. It will be seen from the accompanying illustration that the input of the device consists of an ordinary transformer R, of which the secondary is connected to the grids of two valves V. An impedance in the form of a resistance L is connected between the secondary and the filament through a grid battery B. The explanation of the device as given by the inventor is as follows: When an alternating voltage is applied to the primary, the voltage on the secondary will, for half a wave, tend to make one grid more positive and the other grid more negative. If the positive voltage applied to one grid is greater than the voltage of the grid battery B, the grid will become positive and grid current will commence. The grid current has a double effect. First, it establishes a temporary connection between that end of the secondary and the filament. Secondly, it gives the secondary as a whole a negative charge, which in leaking down the resistance L, causes a volt drop that has the same effect as an increase in the biasing voltage. Thus an automatic grid bias equal to the peak voltage applied to the grid is obtained in the same way as with the familiar grid leak and condenser method of rectification. The scheme as outlined above should prove an interesting subject for experimental work.



INTERFERENCE ELIMINATION.

(Convention date, June 13, 1923. No. 217,601.)

British Patent No. 217,601, granted to Telefunken Gesellschaft fur Drahtlose Telegraphie, describes a selective circuit arrangement illustrated by the accompanying diagram. The specification describes an apparatus suitable for insertion between the aerial and earth terminals and a receiver. Between the aerial and earth there is a condenser C, having a capacity of two or three times that of the aerial-earth capacity. The normal tuning circuit of the receiver is the inductance L and the capacity E, the potential to be applied to the grid of the first valve being taken across the inductance L. This tuned circuit LE is connected across the condenser C, through another condenser D, the capacity of which is not stated. Without further information regarding the constants of the circuit it is rather difficult to see exactly in what manner the selectivity is obtained.



AN INTERESTING RECEIVER.

(Application date, July 2, 1923. No. 222,562.)

N. Ashbridge describes in British Patent No. 222,562 a receiving system which is suitable for

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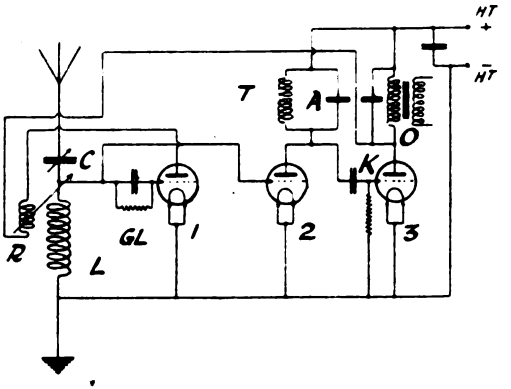
rapid search and should be very suitable for amateur use. Although three valves 1, 2 and 3 are shown in the diagram, the receiver is only intended to operate as a single valve receiver or as a tuned anode and detector. It will be seen that the ordinary aerial tuning circuit LC is connected to the grid and filament of valve 1, through a grid condenser and leak and also directly across the grid and filament of the second valve 2. The anode circuit



of the second valve 2, contains a tuned circuit TA, which can be tuned to the desired signal. The anode of the second valve is coupled to the grid of valve 3 through a capacity K, and the grid is connected to the filament through another leak. The anode circuit of the first valve contains a reaction coil R, which is connected in series with the primary of an output transformer O, or a telephone receiver. The primary of the output transformer is also included in the anode circuit of the third valve. The receiver is used in the following manner: In order to search for a station the filaments of the valves 2 and 3 are switched off and the first valve is used alone. It will be seen that the circuit is now functioning as a single valve reaction receiver. When the desired station has been picked up the filaments of the other two valves are switched on. The third valve now acts as a detector and the second valve as a high frequency amplifier. The great advantage of the system is that whatever may be the tuning of the anode circuit of valve 2 the signal will not be lost, although it may be slightly weakened owing to the extra loading of the grid circuit of valve 2. The anode circuit of valve 2 is then accurately tuned and should the system tend to oscillate, the coupling of the reaction coil is reduced. We imagine that the above circuit arrangement should be appreciated by the wireless experimenter who spends much of his time searching the ether for transatlantic amateur signals.

A NEW GAS DISCHARGE DEVICE.

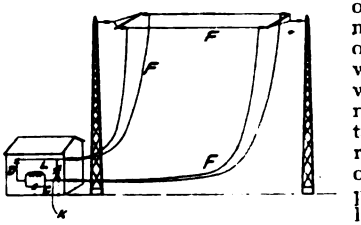
(*Convention date, January* 31, 1923. *No.* 210,728.)

A patent numbered as above assigned to the General Electric Co., Ltd., from Germany describes a gas discharge tube in which other than the rarer gases may be successfully employed. The well-known Moore lamps filled with nitrogen or carbon dioxide had to be provided with some means for maintaining a constant supply and pressure of gas. The object of the invention is to provide a discharge device containing a chemically active gas which shall be fairly constant in operation. This is achieved by using electrodes made of conducting chemical compounds. For example, when oxygen or carbon dioxide are employed magnetic iron ore (magnetite) is suitable. On the other hand when nitrogen is used, nitrides, such as zirconium, titanium and vanadium nitrides are employed. Sulphur containing gas or sulphur vapour with galena electrodes is also mentioned. Although the idea is no doubt originally intended for illumination purposes there seems to be no reason why it should not be applied for radio purposes in a similar manner to that in which the neon lamp is frequently used.

SELECTIVE RECEPTION.

(*Application date, July* 23, 1923. *No.* 223,642.)

A system of selective reception which should be of interest to amateur experimenters is described in British Patent No. 223,642 by A. W. Sharman. The system consists in using an exceedingly large loop or frame aerial in conjunction with rejector circuits. In the accompanying illustration the aerial F is shown supported between two masts and is tuned as a closed loop by the condenser K. Another feature of the invention is that the total effective length of the aerial is not less than one-sixth of the wave-length which is to be received. Owing to the size and relative lengths of the components of the loop there is little directional effect.

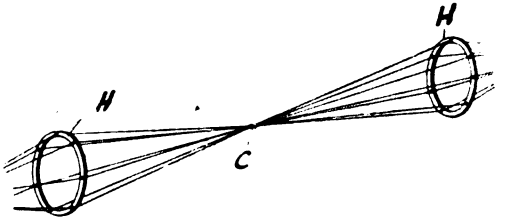


The potentials produced across the ends of the loop are rectified by means of a detector or other device D. The detector circuit is not connected directly across the ends of the loop, but is in series with a rejector circuit LC. The invention provides for various modifications of the receiving circuits.

AERIAL CONSTRUCTION.

(*Application date, October* 27, 1923. *No.* 223,742.)

A rather peculiar type of aerial is described by J. W. Fothergill in British Patent No. 223,742.



It will be seen from the accompanying illustration that the aerial consists essentially of a series of

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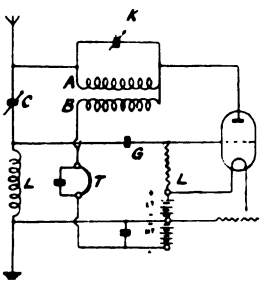
conical shaped sections. It is made by fixing a number of wires round the periphery of hoops H in a manner similar to that used in the construction of the ordinary cage type aerial. Between each pair of hoops there is a "contractor" C, which is simply a small tube through which the wires are passed. It is stated that the object of the invention is to obtain increased efficiency, but we fail to see exactly how this was obtained with the construction described in the specification.

A PECULIAR SINGLE VALVE RECEIVER.

(*Application date, October* 24, 1923. *No.* 223,061.)

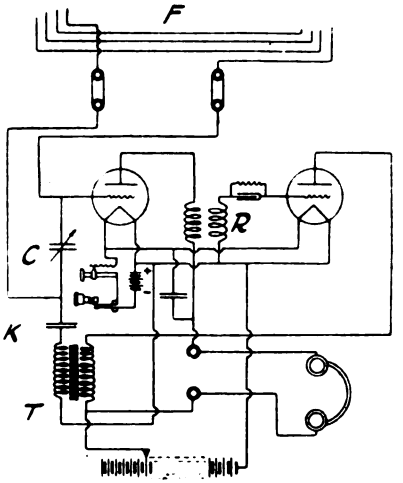
The above British Patent granted to Mann, Egerton & Co., Ltd., and H. R. Taunton, describes a type of receiving circuit illustrated in the accompanying diagram. The most peculiar feature lies not so much in the circuit itself, but in the construction of the "transformer" AB. It is stated that for broadcast wave-lengths two concentric coils A and B are wound with about 14 and 56 turns respectively, but it is also stated that the ratio may be between one to two and one to six. The aerial circuit consists of a capacity C, in series with an inductance L, which is connected across the grid and filament. The anode circuit consists of the secondary winding of the special transformer and the telephone receivers T. The valve acts as a detector by means of the grid condenser G, and leak L. Reaction is obtained through the special transformer, since it is indirectly coupled to the grid circuit. It will be noticed that the primary winding A is tuned by the condenser K, one end being connected to the anode and the other to the aerial and simply functions as an ordinary shunt reaction device. It is stated that the arrangement is particularly stable in operation.



A REFLEX CIRCUIT.

(*Application date, July* 23, 1923. *No.* 223,648.)

A. W. Sharman describes in British Patent No. 223,648 a type of reflex circuit which is illustrated by the accompanying diagram. The novelty of the circuit lies in the scheme used for determining the grid potential of the first valve. It will be noticed that the first valve functions as a dual amplifier, the anode circuit of which is coupled by the radio-frequency transformer R to the second valve which acts as a detector. The anode circuit of the detector valve contains the primary winding of an audio-frequency transformer T. In a normal reflex circuit the secondary of the transformer is connected directly in the grid circuit on the earth side. In this particular case the receiver is shown with a loop aerial F, which is tuned by the variable condenser C. One side of this tuned circuit FC is connected to the grid of the dual valve, and the lower end, instead of going directly to the secondary of the transformer, is

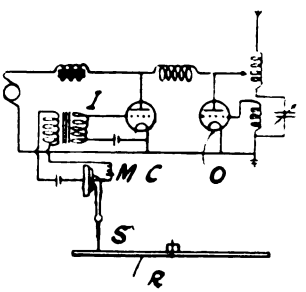


joined through a condenser K of small capacity. It will be apparent that the grid is accordingly isolated, and will therefore assume a negative potential. It is stated that this negative potential is sufficient to prevent the system from oscillating, and also that the valve is in its most sensitive and responsive condition. Exactly why this is the case is not altogether apparent. It seems to us that if the sole function of the condenser is to maintain a desired grid potential it would be more practical to utilise grid cells or a potentiometer and at the same time eliminate the disadvantages of a free grid.

SECRET TRANSMISSION.

(*Application date, August* 22, 1923. *No.* 224,621.)

Vickers Limited and C. P. Ryan describe a system of secret transmission in British Patent No. 224,621, which is illustrated by the accompanying diagram. The valve O and the associated circuits represent an ordinary radio-frequency oscillator, while the valve C and associated circuits represent the usual form of control. The input to the control valve is the transformer I, the primary of which is connected to a special microphone M. The microphone M is connected to a stylus S, which is in contact with a gramophone record or similar device R. The invention relates



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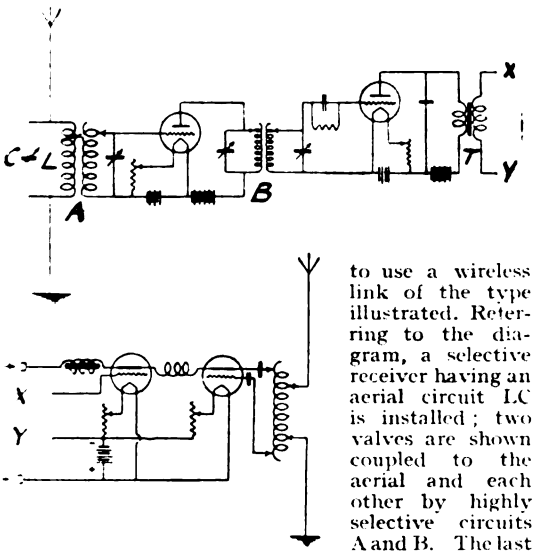
to control rather than to the transmission of intelligence and the record is arranged to transmit, when run at the correct speed, a predetermined series of acoustic signals. Interposed between the correct signals there are a number of interfering signals of various acoustic frequencies which renders the transmission unintelligible to any but authorised receiving stations.

AUTOMATIC RELAY OF BROADCASTING.

(*Application date, June* 27, 1923. *No.* 222,547.)

A. W. Sharman describes in British Patent No. 222,547 a system of broadcast transmission which is illustrated in the accompanying diagram. The object of the invention is to overcome the difficulties of reception in districts where the conditions are unfavourable for the use of ordinary broadcast receivers. In order to obviate the use of land lines connecting the main station with relay stations, it is proposed



to use a wireless link of the type illustrated. Referring to the diagram, a selective receiver having an aerial circuit LC is installed; two valves are shown coupled to the aerial and each other by highly selective circuits A and B. The last valve acts as a rectifier and is coupled by an output transformer T, which is connected at XY to the control valve of a low power transmitter. The system does not appear very novel to us, as we think similar schemes have been used prior to June, 1923. The idea of a wireless link, while being excellent from many points of view, always suffers from the effects of interference and atmospherics.

AN IMPROVED GROUND AERIAL.

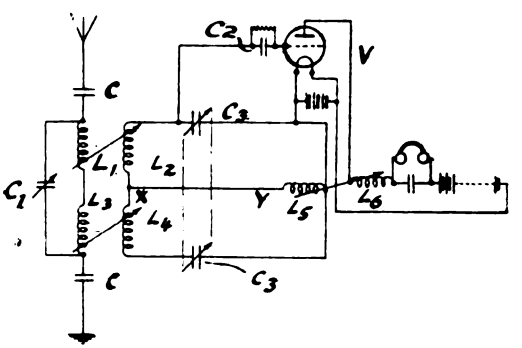
(*Application date, September* 28, 1923. *No.* 224,661.)

H. P. T. Lefroy describes in British Patent No. 224,661 an improved form of buried aerial. Ground aerials which have been previously used have generally taken the form of rubber-covered wire laid on the surface of the ground or merely buried just below the surface. Both these types of aerial have been subject to fairly considerable high frequency losses. These losses, which are chiefly due to dielectric hysteresis, are considerably reduced in the present invention by placing the aerial in a tunnel or chamber which either contains air, a gas, or is evacuated. It is stated that the tunnel may be a trench about two feet wide, at any depth below the surface of the ground. A tunnel aerial, it is claimed, gives greater freedom from atmospheric disturbances and stronger signals are obtained with greater selectivity.

PREVENTION OF RADIATION.

(*Application date, June* 27, 1923 *No.* 220,765.)

N. P. Hinton describes an interesting anti-radiation circuit in British Patent No. 220,765. In the accompanying illustration the aerial circuit comprises two condensers C, on either side of the split inductance L_1 L_3, which is tuned by C_1. Inductance L_1 and L_3 are coupled to two identical inductances L_2, L_4, which are in circuit with two equal variable condensers C_2, C_3. The mid points of the inductances and condensers are joined by a common wire through an inductance L_5, which is coupled to L_6 in the anode circuit of a valve V, while the condenser C_2 is connected to the grid circuit of the valve. It is easily seen that current induced into L_5 from L_6 will flow along the neutral wire XY, and will be in opposite phase relation in L_2 and L_4. Since L_2 is part of the grid circuit



a reaction effect is obtained between L_2 and L_4 resulting in increased signals. Should oscillations be generated, it is stated that the currents being equal and of opposite phase in L_2 and L_4, their combined induced effect in L_1, L_5 in the aerial circuit will be substantially zero, or in other words there will be no radiation from the aerial.

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EXPERIMENTAL WIRELESS & The WIRELESS ENGINEER

VOL. II. APRIL, 1925. No. 19.

Editorial Views.

H.F. Resistance.

IN accordance with the announcement made in our last month's issue, it will be found that considerable space is devoted this month to Professor Fortescue's paper on "Resistance in Wireless Circuits," read before the Radio Society of Great Britain on February 25, and to the discussion on it. The paper was an exceptionally interesting one, although it dealt with a subject with which all readers are supposed already to be conversant. None the less, we think that they will find considerable new matter for consideration in the paper. Unfortunately, some of the most interesting points will necessarily be lost in our report, since they depended upon actual demonstration. The apparatus exhibited at the reading of the paper, designed to draw a resonance curve automatically, was most interesting. Some of the figures given by Professor Fortescue as the results of actual tests on the high frequency resistance of commercial apparatus, will, we think, surprise readers.

These results, together with the article in our last issue on methods of measuring H.F. resistance, seem to us to point out a very useful series of measurements which might be made by some of our readers; a comprehensive set of results on both home-built and commercial coils.

The makers of coils frequently publish the values of self-capacity; but to the best of our knowledge there is little information as to resistance. The measurements should be carried out in each case on a wave-length for which the coil is likely to be used, and it would probably be best to express the results as power factors. This is easily done, since the power factor is simply resistance divided by reactance, and the reactance is 1 885 times the inductance (in microhenries) divided by the wave-length in metres.

We suggest this form for the results since, although the power factor of a coil is by no means constant, it does not vary nearly so much as the resistance.

The apparatus required for such tests is by no means elaborate, if approximate results only are required.

Using the Willans method, one needs only a wavemeter, a good condenser, and three or four H.F. resistors; the latter are very cheap to make.

The work involves finding the inductance of the coil, and its self-capacity is automatically found during the process. The greatest trouble is really the checking and tabulating of the results. We do not know whether any readers have the energy to spend a month or two's spare time on such work, but if they do we shall be only too pleased to assist in any way possible.

Classification.

With this issue we come to the end of our series on the Arrangement of Wireless Books

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and Information. The purely wireless classification was in fact completed in last month's issue, and the list this month comprises excerpts from the main Dewey list, dealing with matters which (although not purely wireless) will often be needed for reference. We have also devoted some space under this heading to a few short notes on the actual routine of filing and indexing cuttings, and so forth. It will, we trust, be realised by those interested that our extensions of the classification, which throughout have been marked as such, must be regarded as provisional. We shall be much indebted to any readers who may be making use of the scheme, if they will write to us after some experience of the classification, letting us know of any difficulties they may find in deciding where items are to go, and giving us their views on any possible improvements.

The Paris Conference.

Immediately after the Easter holiday there will be held at Paris (as our readers are probably aware) an important Congress, at which it is proposed to found an International Union of Wireless Amateurs. The conference opens on Tuesday, April 14, with a general session, at which detailed arrangements will be made for the routine. On the following three days, the mornings will be devoted to visits to various centres of wireless interest in or near Paris. Wednesday's visit is to the Eiffel Tower station, Thursday's that to the works of M. Belin, where visitors will be able to see the telegraphic and wireless transmission of photographs, and Friday's to the high-power station at Sainte-Assise. The congress meetings will be held in the afternoons, and are to deal with the following agenda :—

(1) Detailed organisation of the proposed International Union of Amateurs ;

(2) Standard organisation for international test work and communication ;

(3) Proposals for the allotment of wavelengths for amateurs, and broadcasting ;

(4) The possibilities of an auxiliary international language for wireless work ;

and such other matters as may arise.

It is to be noted that the power of voting on resolutions put forward is confined to the official delegates of the various countries—in the case of Great Britain to representatives of the Radio Society of Great Britain. At the same time, it appears that opportunity will be offered to all attending the conference to express their views if they desire.

Readers desiring to attend the conference should apply before April 7 to H. Epton, Esq., 17, Chatsworth Road, E.5, who is making arrangements for inclusive terms to cover travel and other expenses.

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The Arrangement of Wireless Books and Information.

Part VII. and Last. [R025·4

The last list of subjects is preceded by some practical hints on using the system.

BELOW we give, as a finale to our extension of the Bureau of Standards extension of the Dewey system, a few items from the Dewey tables themselves. We have selected these as being subjects with which wireless has been or is likely to be concerned, and considerations of space prevent us from dealing with them as fully as we wish.

Unfortunately the full tables form a rather large and expensive book,* and it is unlikely that many readers will be enthusiastic enough to purchase it. We shall always be pleased to send *short* extracts from it to anyone interested in a particular subject.

Using Dewey.

It would seem that this is an appropriate place to give a few words as to the practical use of the system.

The main idea, of course, is to preserve just what one wants from the large amount of published matter on wireless, and to arrange matters so that one can easily lay one's hand on all that one has on a certain definite subject. The information will usually fall under three headings :—

(*a*) Books, or odd pages or chapters of books.

(*b*) Cuttings from periodicals.

(*c*) One's own notes.

The matter in class (*a*) at once brings up an important question: Shall we arrange the matter itself on the logical system, or shall we keep the matter in some arbitrary order and keep an index to it arranged logically ?

Obviously we must adopt the latter principle as regards books, unless we are prepared actually to break up the books. It is therefore really more consistent to do this as regards all the matter, although it puts us to the trouble of writing index cards for them. At the same time, there are important advantages to be gained by keeping cuttings or isolated papers in logical order, since in this way all matter dealing with a particular subject is kept together. The fundamental difficulty is that in many cases the same article deals with various phases of a subject, or sometimes various subjects. Obviously the article itself can only be kept in one place, so we are again brought back to indexing, for an article can be *indexed* under as many heads as we like, on different cards.

The method finally recommended is as follows :—

(*a*) BOOKS. These are kept in classification order. Where, as is usual, a book contains matter on various subjects, or phases of the same subject, it is placed under

R140

CONTINUOUS WAVE WIRELESS TELEGRAPHY.

W. H. ECCLES.

Vol. I. (Vol. II. not yet appeared).

Kept under R140.

Also :

R131 ; R142·5.

Actual size 5 in. × 3 in.

Fig. 1.

* "The Dewey Decimal Classification and Relative Index." Grafton & Co., London, 36/- net.

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a general heading if there is a suitable one; if not under that subject which it treats of most fully.

For example, a book dealing generally with valve receivers will probably contain matter covered by R341, R342, and R343. It will be filed under R340. On the other hand, a book such as Nottage's "Calculation and Measurement of Inductance and Capacity" contains matter on R145, R220, and R230. It is usually simplest to place the book itself under the first heading (R145), with index cards under each.

An important point arises in connection with fairly general text-books covering a wide range—such books as would usually go under R020. It will nearly always be found that one or two particular points are dealt with in a way that particularly appeals to the individual concerned. These should be indexed separately under their own headings.

For example, Morecroft's "Principles of Radio Communication" deals with a very wide range. Among the points which particularly interest the writer is his treatment of the self-capacity of coils, and a special reference to these pages is made in the index under R382·1—Qualities of an Inductor.

(*b*) PERIODICALS. Those that we consider to have a sufficiently large percentage of permanently interesting matter are kept complete, each set being kept in order of appearance. Items of interest are indexed logically.

From other periodicals, the interesting matter should be cut, and kept in press-cutting books. Various schemes have been suggested by which the cuttings are mounted on stiff leaves to be held in loose-leaf binders so that they themselves can be arranged in logical order. But they have not been very successful, and our own preference is to get a broad classification by opening up several press-cutting books—say one for each main class—and arranging cuttings in order as they come to hand, leaving the index to do the classification.

One important point as the selection of matter to be kept: do not be too exclusive. The enthusiast in DX reception is often tempted to scrap matter on the distortionless reception of broadcasting, and *vice versa*—only to find a year later that he wants it.

(*c*) ONE'S OWN NOTES. These are treated in the same way as cuttings. One caution, however, is necessary. Be careful to give a full title and date, and do not make the notes too abbreviated. Matter that is quite clear *now*, while it is fresh in the mind, may be practically unintelligible a year hence, if other branches of work have occupied us in the meanwhile.

R411·0124

SPARK FOR SHORT WAVES, BY MIXTURE OF METAL FILINGS AND OIL.

J. TAYLOR, B.Sc.

(quoting *Zeit. fur Physik*, 24, B.3 and 4, H., p. 153).

E.W. & W.E., Mar./25, p. 342.

P—C Bk. 4, p. 78.

Also:

R401·24.

Actual size 5 in. × 3 in.

Fig. 2.

The Index.

Lastly, as to the index itself. This is obviously kept on cards. When making out a card for a book, start by putting the Dewey number in the top right corner. At the bottom give any other numbers in which the book is also indexed.

As an example, take Eccles' "Continuous Wave Wireless Telegraphy." This deals mainly with A.C. circuits, but also with valve characteristics, and is specially interesting to the indexer for, say, its treatment of capacity coupling.

Fig. 1 shows one of the three cards made for it. The others each have a different number in the top corner, the other two numbers being relegated to the bottom. A few notes on the size and scope of the book are often useful.

As an example of dealing with a cutting, we have selected the short article on "A New Method of Producing Ultra-Short Waves," by J. Taylor, B.Sc., in last month's issue. First suppose that this is cut out and kept in (say) Press-Cutting Book No. 4, on p. 78.

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The card will be as Fig. 2, giving two references, to spark systems and extra-short wave systems respectively. As a rule, ignore the exact title of the article, or put it low down on the card, giving first the actual "meat" for which the cutting is kept. If, by some miracle, it had been decided that *all* of E.W. & W.E. were worth keeping, the reference to year, month, and page would stand, that to the press-cutting book being deleted.

R800 Non-Wireless Subjects.

The following numbers, derived from the Dewey classification itself, should *not* be preceded by "R."

010				Bibliography.
				Reserved for lists of books, etc
020				Library economy.
	025			Management.
		025·3		Catalogues.
		·4		Classification.
069				Museums.

300 Sociology.

	330			Political Economy.
	331			Labour, Employer, etc.
	337			Protection and Free Trade.
340				Law.
	341			International Law.
	347			Patents.
	355			Military Science.
360				Associations and Institutions.
	362			Hospitals, etc.
	368			Insurance.
370				Education, schools.
	374			Home and Self-Education.
	378			Colleges and Universities.

400 Philology, Language.

	499			International languages.

500 Science.

510				Mathematics.
		510·8		Mathematical tables and instruments.
	511			Arithmetic: computation
	512			Algebra
		512·8		Higher Algebra.
	513			Geometry.
		513·3		Solid Geometry.
		·8		Non-Euclidean Geometry.
	514			Trigonometry.
	516			Analytical Geometry.
		516·12		Graphs, etc.
	517			Calculus.
		517·2		Differential.
		·3		Integral.
		·8		Imaginary quantities.
	519			Probabilities.
		519·6		Errors of observation.
		·8		Method of least squares.

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520 Astronomy.
- 525 The Earth.
  - 525·4 Longitude measurement.
- 529 Chronology: science of time.
  - 529·7 Horology.
  - ·76 Distribution of time.

530 Physics.
- 531 Mechanics.
- 532 Hydraulics, etc.
- 533 Pneumatics.
  - 533·85 Vacuum pumps, etc.
- 534 Sound; acoustics.
- 535 Light; Optics.
  - 535·3 Photo-electrics.
- 536 Heat.
  - 536·33 Radiation in general.
- 537 Electricity.
  - 537·1 Theory: nature.
  - ·2 Static.
  - ·4 Atmospheric.
  - ·6 Electro-dynamics.
  - 537·7 Electric measurements.
- 538 Magnetism.
- 539 Molecular physics.
  - 539·1 Theory: Molecular structure.
  - ·6 Intermolecular forces.
  - ·7 Radioactivity.

540 Chemistry.
- 548 Crystallography.
- 549 Mineralogy.
  - 551·5 Meteorology.

600 Useful Arts.

610 Medicine.

620 Engineering.
- 621 Mechanical.
  - 621·3 Electrical
    - ·31 Generation.
      - ·313 Dynamo-electric machinery.
      - ·313·2 D.C.
        - ·23 Dynamos.
        - ·24 Motors.
        - ·25 Converters.
        - ·3 A.C.
        - ·35 Converters.
        - ·355 Frequency Converters.
        - ·7 Rectifiers.
      - ·314 Transformers, etc.
      - ·315 Condensers.
      - ·316 Details and parts.
      - ·317 Wiring and switchgear.
    - ·32 Lighting.
      - ·327 Lamps, etc. (includes valves)
    - ·35 Chemical electricity.
      - ·351 General, EMF, polorisation, etc.
      - ·352 Parts and accessories of batteries.
      - ·353 Primary cells.
      - ·354 Accumulators.
      - ·354·3 Battery Charging.
      - ·355 Lead accumulators.
      - ·356 Alkaline accumulators.
      - ·36 Thermopiles, etc.
      - ·37 Measurements.

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·374 Especial apparatus for testing :—
·374·2 Resistance.
·3 Voltage.
·4 Current.
·5 Work.
·6 Power.
·7 Frequency and wave-form.
·9 Other.
·38 Communication.
·382 Telegraphy.
·384 Wireless.
·385 Telephony.
622 Mining.
623 Military engineering.
623·7 Signals.
625 Railway and road engineering.
629 Various.
629·13 Aviation.
·2 Motor vehicles.

630 Agriculture.

640 Domestic Economy.

650 Commerce, Communication.
655 Printing and Publishing.

670 Manufactures classed by materials.
671 Metals.
674 Timber.
676 Paper.
677 Textile.
678 Rubber.
679 Celluloid and other.

680 Mechanic trades.
681 Watches and instruments.

700 Fine Arts.

770 Photography.

780 Music.
781 Theory.
782 Dramatic (Opera, etc.).
783 Sacred.
784 Vocal.
785 Orchestral.
786 Piano and organ.
786·1 Piano.
·5 Organ.
787 Stringed instruments.
788 Wind ,,
788·1—·4 Brass.
·5 Flute, etc.
·6—·9 Reed (oboes, etc.).
789 Percussion (drums, etc.)
789·9 Mechanical—Piano-player, Gramophone, etc.

790 Amusements, Hobbies, Sport, etc.

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Harmonics. [R146

An attempt to correct one or two common fallacies, together with a note on the use of wave-meters.

IT is a moot question whether harmonics are viewed as a curse or a blessing by the majority of my readers. But, whatever one's opinion, they are important, and there seem to be some misconceptions current about them, which we feel ought to be cleared up.

We have spoken above of an "impure source." This is not a reference to an originator of smoking-room anecdotes, but means a generator which gives a current not of pure sine form. Most generators actually are of this type, and as a rule the valve oscillator has a fine series of harmonics.

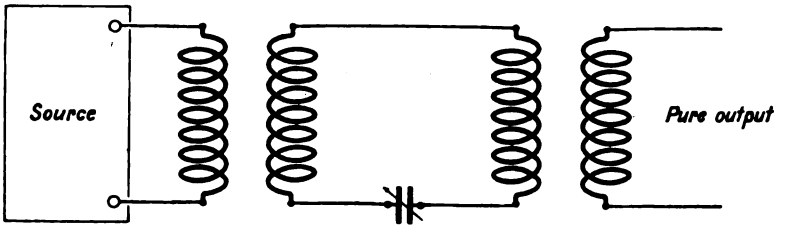

Fig. 1.

Firstly, what is a harmonic ? Not so easy to define as it seems. Generally speaking, it is a current or voltage of a frequency, an exact multiple of some fundamental frequency, we are considering. For example, any current which is not a pure sine-wave may be considered to consist of a fundamental sine-wave component of the frequency we are tuned for or dealing with, together with sine-wave components of other frequencies, each of which is an exact multiple of the fundamental. Note this last clause. As we shall see later, the point is important.

There seems to be an idea that a circuit "tuned" to a frequency — say 1 000kc (1 000kc = 1 000 kilocycles = 1 000 000 cycles = 300 metres)—is also tuned to the harmonic frequency, 2 000kc or 150 metres. This is quite a mistake. A simple tuned circuit is a good *filter* for harmonics. Its reactance is zero to the fundamental frequency, but large to all others: it does not favour the harmonics at all ; in fact, if we wish to get a pure sine-wave from a source containing harmonics, we can do it by a circuit such as Fig. 1, where the central circuit is tuned. We can, if desired, tune the intermediate circuit to one of the harmonics, when this one alone will pass on to the output circuit.

If the valve has a characteristic like Fig. 2, one may by careful handling cause the grid to swing only over a small range when the output will be as shown in the figure—very nearly a pure sine-curve ; the harmonics will be small. It is more likely, however, that the grid will have a greater

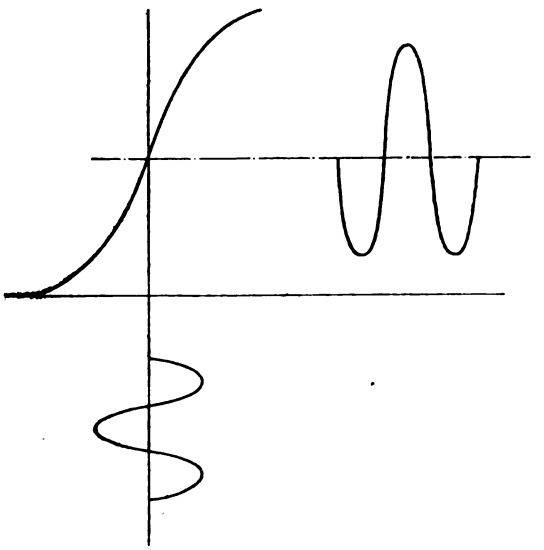

Fig. 2.

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swing, as in Fig. 3, in which case the output will be as shown on the right. It is a flat-topped curve, containing a strong third

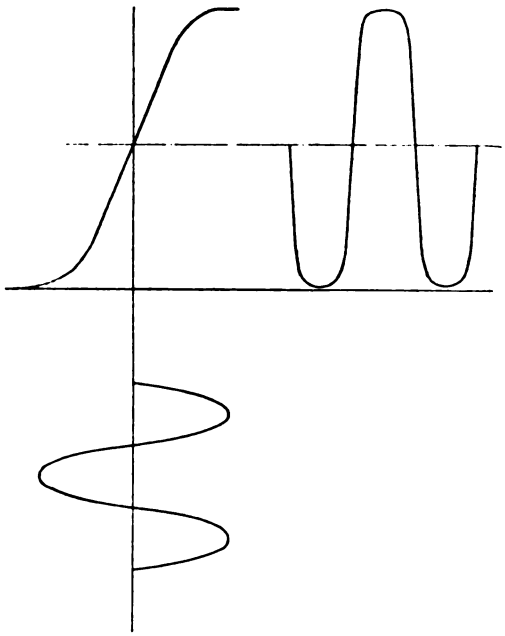

Fig. 3.

harmonic among others. It is notable that if the valve curve is symmetrical about the mid-line of the steady grid potential, the positive and negative half-waves of the output should be exactly similar. If this is so, there will be only odd harmonics: i.e., if the fundamental is of 1 000kc, the output will be a mixture of 1 000, 3 000, 5 000kc, etc., or 300, 100, 60 metres, etc.: *not* the other harmonics of 2 000, 4 000kc, etc.

But suppose the grid is biased or the H.T. altered, so that the grid swing is as shown in Fig. 4, we have a very different state of affairs. The positive and negative half-waves of the output are unequal, and the even as well as the odd harmonics will be present in the output.

The Aerial Circuit.

Next, the aerial circuit. Here there is a peculiar state of affairs. An aerial, because its inductance and capacity are distributed, *is* tuned to several frequencies at once. But, except in one particular case, the higher frequencies are *not* harmonics. Their frequencies are not exact multiples of the fundamental except in the particular case where the aerial has neither inductance nor capacity in its circuit. *In every ordinary case, the "overtones" in an aerial are at frequencies whose ratios to the fundamental depends on the amount of loading inductance and capacity.*

The reader may well ask, why then do I hear London on exactly one-fourth of its fundamental? The reason is simple: this harmonic—among others—is present in the valve output, and is to a certain extent forced on the aerial, especially if its frequency is *near* one of the aerial's natural overtones. It is a natural harmonic from the valve transmitter that is heard, not one of the aerial.

Wavemeter Harmonics.

Perhaps the most frequent encounter of the amateur with harmonics is in the use of the valve wavemeter. Most of these instruments emit a wave with many harmonics, which fact may be a convenience or the reverse according to circumstances. For example, in our own laboratory we use the harmonics of our standard wavemeter for

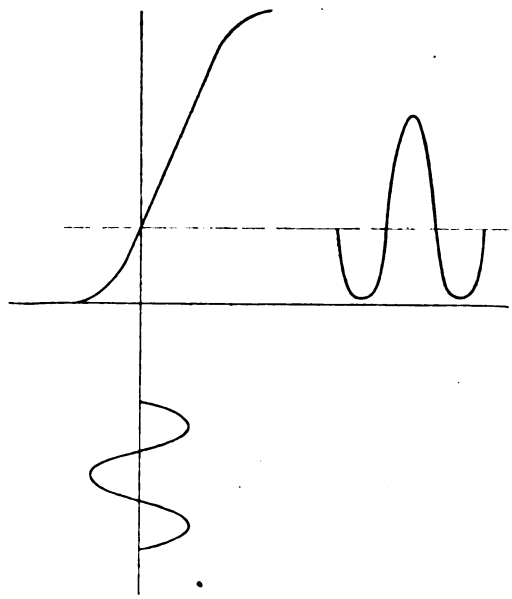

Fig. 4.

all frequencies above 3 000kc (wave lengths below 100 metres), which saves having a special instrument for these waves.

At the same time, the fact is sometimes an embarrassment, for it leads to a real difficulty

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in finding what is the real tuning of an unknown wavemeter which is being calibrated—though, as will be shown later, the difficulty is easily got over. As the trouble is one which arises not only in calibration work, but also in the ordinary use of a wavemeter, we will go into it a little.

Assume that we are using a wavemeter to check another valve instrument—a transmitter or oscillating receiver. We set one instrument and swing the condenser of the other, listening for a chirp. Now, whenever the frequency of the varying circuit crosses that of the one which is remaining fixed for the time, we get the chirp: but we also get it if our varying circuit is emitting harmonics, and one of these crosses the "fixed" frequency. Thus, if the circuit we are testing happens to be tuned to 100 metres, we shall get a chirp when our wavemeter crosses 100, 200, 300, . . ., etc. metres, for in each case there is a harmonic at 100 metres.

But there is more than this. In all probability the fixed instrument is also emitting harmonics, and we shall get a chirp whenever *any* harmonic of one "crosses" *any* harmonic of the other!

For example, suppose the fixed instrument is emitting on 100, 50, 33, and 25 metres, and the varying one on the same four harmonics—second, third, and fourth—as well as on its fundamental.

Then, as before, we shall get a chirp at 100 metres on the meter which we are varying. But we shall get another at 133 metres, when the fourth harmonic of one and the third of the other are both 33 metres; again at 150, when the third of one and the second of the other are both 50 metres, and further chirps at 200, 300 and 400 metres.

To make sure just what may happen in practice, we set a simple oscillating receiver to beat against our standard wavemeter, which is designed to emit a wave fairly rich in harmonics. We set the receiver to about 250 metres, and steadily increased the wave-length of the wavemeter, watching only for the main beats of the receiver fundamental against wavemeter harmonics. We counted regular chirps every 250 metres up to 5 000. Beyond that they began to get rather faint, and as we were bored we gave it up. It is evident that at least the first twenty harmonics are quite strong in this case.

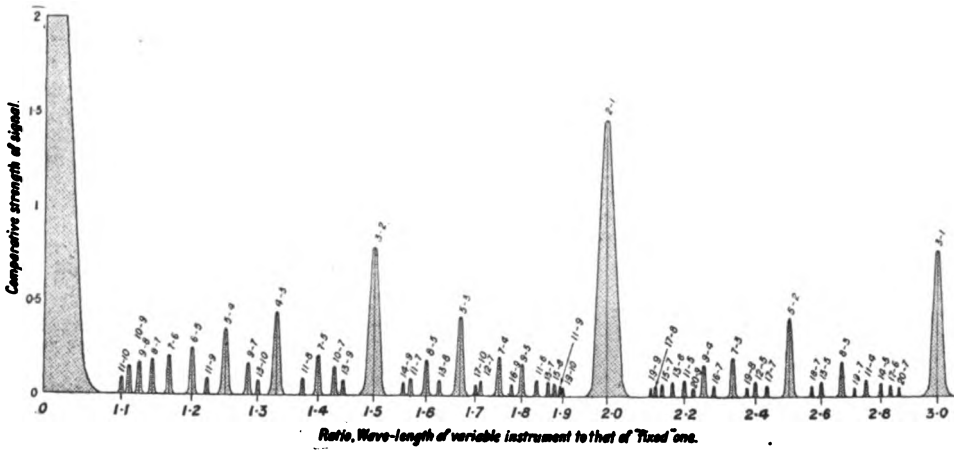

Fig. 5.

To show what may be expected when both instruments are emitting harmonics, we have worked out the case of a varying meter giving up to the twentieth only, beating against a fixed oscillating receiver emitting up to the tenth only. We have only considered the case where the varying instrument is working at a fundamental wave-length above that of the fixed one. A little thought will show that a precisely similar state of affairs will exist for shorter wave settings also.

In Fig. 5 we show, along the base, wave-lengths to a logarithmic scale, the fundamental of the fixed receiver being considered as 1. The existence of a "peak" at any given frequency shows that there will be a chirp on passing through it, and we have tried to

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show, by the height of the peaks, the loudness of the chirp, assuming that the actual strength of the harmonics decreases regularly—*i.e.*, the second weaker than the fundamental, the third weaker than the second, etc.

At the fundamental, 1 on the base line, the chirp is so strong as to be right off the map. It actually rises to 3·55 in the scale used. This is not only because the fundamental is the strongest emission in each case, but also because in this case each harmonic is beating against the corresponding one and adding to the noise. It is interesting to note that when we are off the silent point the note is not a pure one, for the second harmonic in beating set up a note an octave above that of the fundamental, the third harmonic is two octaves above, and so on, as can easily be seen by working it out.

Let us assume that the fundamental is 100 metres. Then at 110 metres we shall get another chirp: the tenth harmonic of our instrument is 10 metres and the eleventh of the other is the same. Eventually we arrive at the results shown in our figure, which goes up to the tenth harmonic. Note that towards the end we are only getting chirps at 8, 8·5, 9, 9·5 times the fundamental. Above 10, we shall get even less—only a chirp at each complete multiple, as 10, 11, 12, etc. And above 20 we shall get nothing if the varying instrument actually emits nothing above the twentieth harmonic. We have shown above each peak the two harmonics that are causing it.

Now suppose we want to find the true fundamental of the "fixed" instrument. If we can get down to this on the varying one there is little difficulty, owing to the overwhelming loudness of the beat between the two fundamentals. But if we cannot, we are faced with a most bewildering job in trying to decide which of the many beats we are actually hearing, and we have known of serious error being made in this way. The cure is easy. We take the varying instrument right up to the long waves, near its limit of harmonics, and find the wavelengths for two or three consecutive beats. The difference between two neighbouring ones is the fundamental frequency.

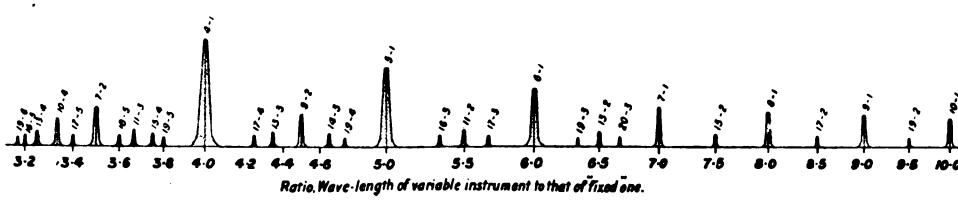

Fig. 5.

It might be noted, in actual work with these harmonics, that they are sometimes very weak compared with the fundamental: in our own work we usually put the output through an L.F. amplifier, as we frequently have to test on through noise. Under these conditions the fundamental beat is unbearably strong, and the harmonics vary from medium to strong telephone strength.

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The Rectifying Detector.

By F. M. Colebrook, B.Sc., D.I.C., A.C.G.I.

Part II. [R149

An exhaustive investigation, theoretical and experimental, into one of the most difficult problems of the Wireless Engineer.

5. Continuous Wave Rectification Efficiency.

A rectifier is a device for transforming high-frequency alternating power into continuous or direct current power, or, in some cases, into a continuous E.M.F. Its merit will therefore be measured by the efficiency with which it performs these operations. This will depend very considerably on the circuit conditions. Four principal cases may be distinguished :—

(A) Current rectification with a constant input potential.

(B) Potential rectification with a constant input potential.

(C) Current rectification with a constant input energy.

(D) Potential rectification with a constant input energy.

The first two of these correspond roughly to any cases in which, by valve retroaction or any other means, the load imposed by the detector circuit can be partly or completely neutralised. The second two assume that the load of the detector causes a fall in available potential, when we must seek for the adjustment of the load due to the total detector circuit to equality with the effective internal resistance of the receiving circuit. (The practical means of realising this condition approximately have been considered by the author elsewhere.*)

The discussion of the constant input potential condition is comparatively simple. The object is to obtain the maximum continuous current power, regardless of the high-frequency power consumed in the process. We have

$$i_0 = \frac{E_c}{R_c+R} \quad .. \quad .. \quad (5\cdot1)$$

It is well known that the maximum power will be obtained when $R=R_c$, i.e.,

$$P_0(max) = \frac{E_c^2}{4R_c} = \frac{i_0^2 R_c}{4} \quad .. \quad .. \quad (5\cdot2)$$

i_0 being the current corresponding to the optimum load. (For reasons already given the R_c in this equation will not necessarily be the same as the apparent internal resistance at no load ; but in practice it will not be very different.) From equation (4·14) the high-frequency power consumed under the same conditions can be determined. Calling this P_1, the efficiency of conversion will be

$$\eta = \frac{E_c^2}{4R_cP_1} \quad .. \quad .. \quad (5\cdot3)$$

In cases (B) and (D), where the object is a rectified potential difference, the corresponding figure of merit will be

$$\eta = E_c/P_1 \quad .. \quad .. \quad (5\cdot4)$$

Both of these expressions will be illustrated by reference to typical rectifiers further on.

The consideration of case (C) is not quite so simple. Here the important factor will be, not the optimum load condition deduced from the form of $\frac{dP_0}{dR}$, but the optimum transformation efficiency, deduced from

$$\frac{d}{dR}\left(\frac{P_0}{P_1}\right)$$

This important distinction can be emphasised by a study of the characteristic specified in section (C) of para. 3. This case is worthy of fairly full consideration because it represents the ideal crystal rectifier, to which actual specimens are a more or less close approximation. Taking the characteristic

$$i = a_1 e \text{ for } e>0 \quad .. \quad .. \quad (5\cdot5)$$
$$= 0 \text{ for } e<0$$

* "More about Crystal Reception." *Wireless World*, July 23, 1924.
"What is the best Circuit for Crystal Reception ?" *Wireless World*, April 30, 1924.

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it can easily be shown that a back E.M.F. v_0 due to a load R will lead to equations 3·18 and 3·20, with v_0 substituted for e_0. (If e_0 is not zero, as in the case of the characteristic given in section (D), the same equations will apply with e_0+v_0 substituted for e_0).

The load equations are therefore

$$i_0 = \frac{a_1 E}{\pi}\left[\sqrt{1-\frac{v_0^2}{E^2}} - \frac{v_0}{E}\left(\frac{\pi}{2} - \arcsin\frac{v_0}{E}\right)\right] \tag{5·6}$$

$$I_1 = \frac{a_1 E}{\pi}\left[\left(\frac{\pi}{2} - \arcsin\frac{v_0}{E}\right) - \frac{v_0}{E}\sqrt{1-\frac{v_0^2}{E^2}}\right] \tag{5·7}$$

These equations cannot be solved directly but the general solutions can be obtained as follows. The expressions within the main brackets are functions of v_0/E, and can be plotted against v_0/E for any desired range of the argument. For known values of a_1 and E the values of i_0 and I_1 can be determined for any value of v_0/E, whence, i_0 and v_0 being known, R can be calculated. For illustration we will take the value $3{\cdot}14\times10^{-2}$ for a_1, making $a_1/\pi=10^{-2}$. The case will then be comparable with that of an ordinary crystal detector. The results are shown in Figs. 16 and 17. The curves show two important facts. For a constant

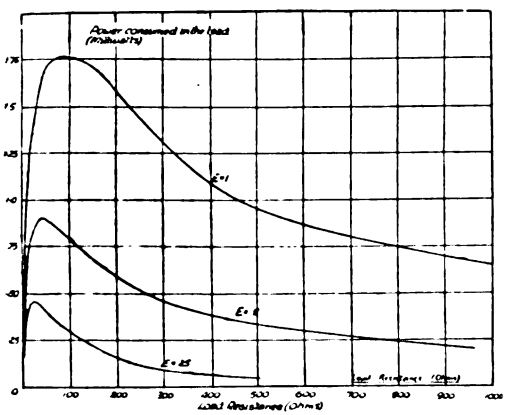

Fig. 16. *Output power, in milliwatts, for various values of load resistance, for an ideal galena crystal.*

input voltage, P_0 reaches a well defined maximum for values of R from 25 to 80 ohms. These figures can be compared with 63·6 ohms, the apparent internal resistance of the rectifier at no load and at large amplitudes. For a constant input energy, however, the curve showing the continuous power developed in the load per unit high-frequency power consumed rises in the detector circuit steadily with R, indicating a maximum when R is exceedingly large. It is further noticeable that the energy efficiency decreases very rapidly with E, also that for small signal amplitudes the increase of energy efficiency with R is not very marked after a certain minimum value of R has been reached.

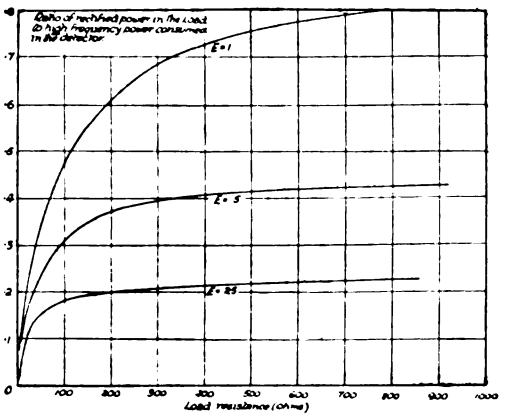

Fig. 17. *Power efficiency corresponding to the curves of Fig. 16.*

The above curves refer only to an ideally simple case. There is, however, sufficient qualitative similarity between the assumed characteristic and that of a good crystal detector to indicate the probable behaviour of the latter. The deductions are, moreover, consistent with experience, and explain what might otherwise appear to be the contradictory facts that though the internal resistance of most crystal detectors is comparatively low, particularly for large signal amplitudes, they appear to operate most efficiently in conjunction with telephones or other recording apparatus of high resistance. It should be pointed out that the actual continuous power obtained under these conditions is considerably less than that corresponding to the real optimum load for the detector considered by itself, but is greater than that which would be obtained with the former optimum load associated with a circuit of constant input energy.

The corresponding cases of potential rectification need not be given in detail. For the perfect rectifier assumed above the final steady state will be $E_c=E$ and $P_1=0$

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for $R=\infty$, i.e., the efficiency is infinite after the steady state has been reached.

For completeness we will consider the other extreme case, corresponding very approximately to the operation of a crystal or other rectifier at very small amplitudes, i.e., the parabolic characteristic

$$i=a_1e+a_2e^2 \quad .. \quad (5\cdot8)$$

The values chosen for illustration will be

$$a_1=10^{-4}$$
$$a=\cdot666\times10^{-3}$$
$$E=\cdot1\text{ V.}$$

These values will be comparable with those for a crystal. The load equations, derived as shown above, will be

$$i_0=a_1\left(\frac{E^2}{2}-\frac{a_1}{a_2}v_0+v_0^2\right) \quad .. \quad (5\cdot9)$$

$$I_1=a_1E\left(1-\frac{2a_2}{a_1}v_0\right) \quad .. \quad (5\cdot10)$$

The results are shown in the curves of Fig. 18. They show the same general characteristics as in the former case, but to a less marked extent. The optimum load for a constant input potential is about 12 500 ohms (compared with $1/a_1=10\,000$ ohms, the internal resistance for no-load). The optimum load for a constant energy input is considerably higher, about 25 000 ohms. It will be seen that the optimum is very flat, and the efficiency only changes by a few per cent. when the load is increased up to 100 000 ohms.

It appears that for small amplitudes there may be an optimum load for both conditions. In practical cases, however, this optimum will again correspond with the use of high

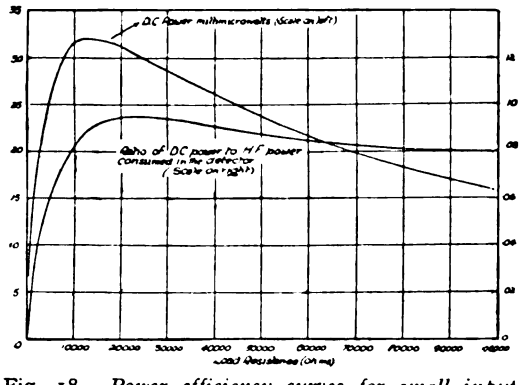

Fig. 18. *Power efficiency curves for small input to an ideal galena.*

resistance apparatus in series with the detector.

This completes the discussion of the efficiency conditions in relation to the rectification of a pure continuous wave. Its modification in the closely related case of the rectification of a modulated continuous wave will be considered later.

Experimental Results on C.W. Efficiency.

It has been pointed out that in the rectification of a continuous wave the maximum D.C. power would be obtained from a given signal amplitude when the D.C. load in series with the detector is equal to the apparent internal resistance of the detector. From the curves of Fig. 9 and

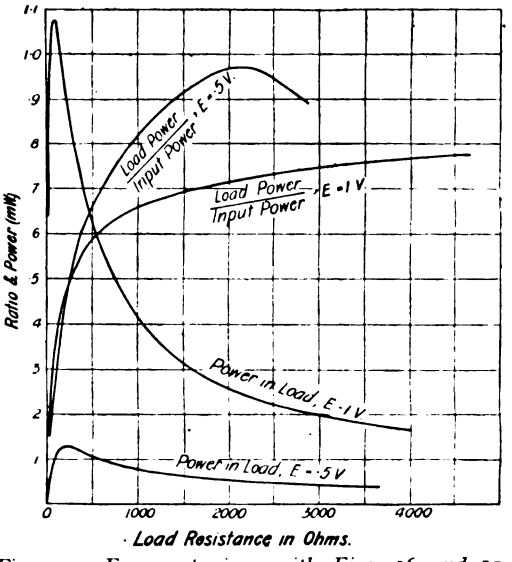

Fig. 19. *For comparison with Figs. 16 and 17, curves are shown for output power and efficiency with the actual galena contact whose characteristics were given in Fig. 9.*

Fig. 10 the variation of the D.C. power (i_0v_0) with R can be calculated. Curves A and C of Fig. 19 show the results for the galena detector. It will be seen that the optimum is very pronounced and that the loads do not differ very greatly from the no-load internal resistance of the detector at the given amplitudes.

In Fig. 20 are given the corresponding curves for small signal amplitudes, calculated from the experimentally determined form of the dynamic characteristic. These latter curves emphasise a peculiar and interesting feature of a curved characteristic, namely,

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that under certain conditions (depending on the ratio between the co-efficients) the apparent rectified E.M.F. may increase so rapidly with the load that the optimum is flattened out to a very marked extent.

It is believed that in many of the practical applications of crystal

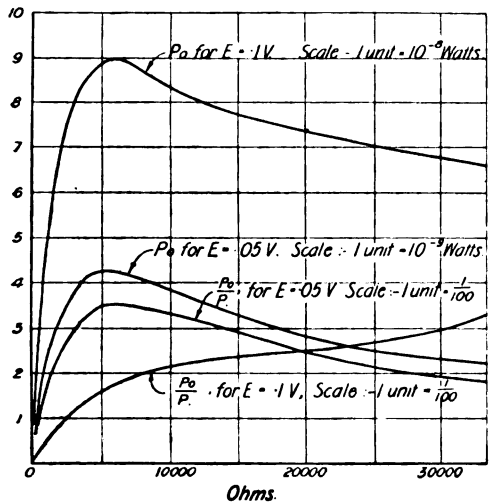

Fig. 20. *The results of Fig. 19 extended for small input voltages.*

detection the most important feature of the detector will be, not the optimum D.C. load corresponding to a constant input E.M.F., but the load condition which gives the highest efficiency of transformation of high-frequency power into D.C. power.

For the investigation of this matter it is necessary to know R_1, the effective high-frequency resistance of the detector circuit under various conditions of load and amplitude. This means that it will be necessary to determine I_1, the amplitude of the fundamental high-frequency component, under the given conditions. In cases where the form of the characteristic can be specified mathematically, I_1 can be calculated as shown in equation 4·14. Where it cannot be so specified, however, as in the case of a crystal detector at moderately large signal amplitudes, the only practicable means of determining I_1 is the somewhat laborious process of graphical analysis of the characteristic. From the form of the rectification characteristic at zero load the probable shape of the dynamic characteristic can be obtained with fair accuracy by the methods indicated in para. 3. From this characteristic the actual form of

$$i=f(e-v_0)$$

(see equation 4·4), for a given value of $e=E\sin\omega t$ and some assumed value of v_0, can be drawn and analysed by any of the usual methods into its continuous component i_0 and its fundamental component I_1. Then, since

$$R_1=\frac{E}{I_1}$$

and

$$R=\frac{v_0}{I_0}$$

we have R_1 in terms of R. The curves of Fig. 21 were obtained in this way. They confirm the statement made in Part I. that the high-frequency load imposed by a detector circuit would vary greatly with the magnitude of the D.C. load in series with the detector, even though the latter is short-circuited by a condenser. The variation of R_1 for the perikon detector was very similar, increasing from about 500 ohms at $R=0$ to about 3 800 ohms at $R=4$ 000.

Having thus determined R_1, the variation with R of P_0/P_1 (i.e., the efficiency of trans-

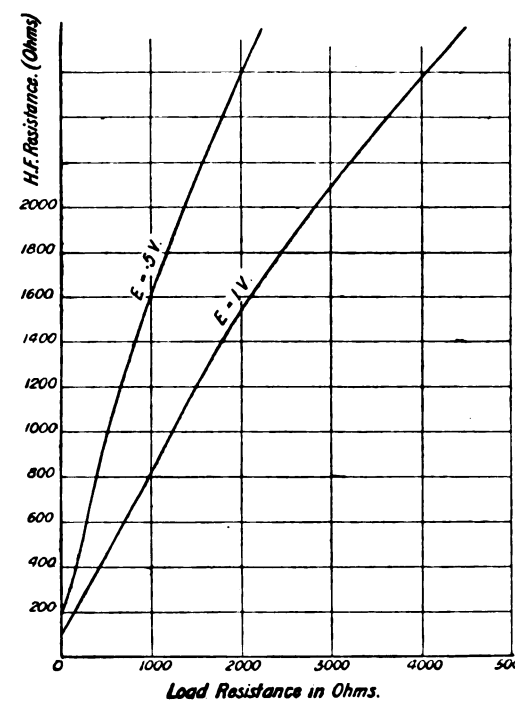

Fig. 21. *Curves of H.F. resistance in terms of output load, by calculation from actual crystal results.*

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formation) can be calculated. The curves of Fig. 19 give the results for galena. It is seen that, as predicted in Part I., the best load resistance from the point of view of efficiency of transformation is very greatly in excess of that corresponding to the maximum D.C. power with a constant input E.M.F.

At small amplitudes the difference will not be so marked, since R_1 will not vary very greatly with R.

The following figures will give some idea as to the relative merits of the two types of detector for the rectification of a continuous wave. With the optimum load for a constant input potential the galena detector will give about 1 milliwatt for a high-frequency amplitude of 1 volt. Under the same conditions the perikon detector would give about ·15 milliwatts. The galena detector will reach a transformation efficiency of 80 to 90 per cent. with a high resistance load (2 000 to 3 000 ohms). The corresponding figure for perikon would be about 60 to 70 per cent., with a somewhat higher resistance load (4 000 to 6 000 ohms). With a signal amplitude of ·1 volt, the galena detector would give about ·09 microwatts at the optimum load, and a transformation efficiency of about 3 per cent. with a higher resistance (30 000 ohms). For the same amplitude the perikon detector would give about ·027 microwatts and a maximum transformation efficiency of about 8 per cent., both with a load of 20 000 ohms.

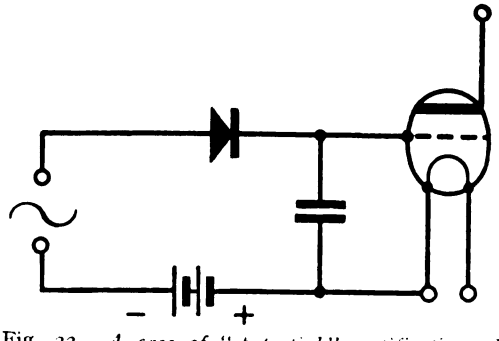

Fig. 22. *A case of "potential" rectification, the valve being of negligible conductance for the D.C. output.*

The figures cannot be regarded as anything more than particular values for these particular specimens, but they indicate the general order of the comparison between the two types of detector.

6. Potential Rectification (Infinite Load).

This has already been mentioned briefly, but is worthy of a little fuller consideration. From equation (4·10), i.e.,

$$i_0 = F(E) - v_0 F_1(E) + \frac{v_0^2}{2!} F_2(E) - \ldots$$

$$\ldots + (-1)^n \frac{v_0^n}{n!} F_n(E) + \ldots \qquad (6\cdot1)$$

it can be seen that if R is increased

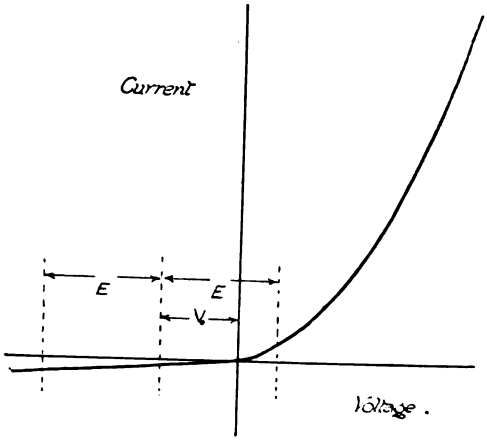

Fig. 23. *The effect of a load of infinite resistance on detection.*

indefinitely, i_0 will reach the limit zero, but v_0 may remain finite, being the solution of

$$F(E) - v_0 F_1(E) + \frac{v_0^2}{2!} F_2(E) - \ldots = 0 \qquad (6\cdot2)$$

A practical example of such a case is that illustrated in Fig. 22, where a crystal detector is connected directly to the grid of a valve, the mean grid potential being sufficiently negative to prevent the flow of any continuous grid current. The process can be related to the detector characteristic as shown in Fig. 23. It is clear that a negative or positive potential charge will accumulate on the plates of the condenser until a value of potential change v_0 is reached, such that

$$\int_0^{\frac{T}{2}} f(E \sin \omega t - v_0).dt =$$

$$\int_{\frac{T}{2}}^{T} f(E \sin \omega t - v_0).dt, \quad .. \quad (6\cdot3)$$

under which condition the positive and

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negative charges added in successive half cycles become equal. For a perfect rectifier, i.e., one in which the conductivity is finite in one direction and zero in the other, the above condition will only be reached when $v_0 = E$. The writer has determined the curves showing v_0 in terms of E for typical specimens of galena and perikon. In the former case it was found (see below) that for moderately large amplitudes (greater than about ·4 volts) nearly perfect rectification is obtained, v_0 reaching as high a value as nearly 0·9 E. Perikon was nearly as effective, v_0 being about 0·7 E for moderately large amplitudes. The curves will be given in the experimental results below.

Experimental Results on Potential Rectification.

The values of E_c corresponding to an infinite D.C. load were measured by means of the circuit shown in Fig. 24. It will be seen that the function of the valve is simply that of a fairly sensitive electro-static voltmeter. The potentiometer arrangement shown across the filament battery is used to balance the normal anode current out of the galvanometer. The valve is calibrated by applying known small changes of mean grid potential and observing the consequent changes of anode current. The curves of Fig. 25 show the results obtained.* The line $E_c = E$ is also drawn on the diagram for comparison. As shown in Part I., this would be the value of E_c corresponding to perfect rectification. The contact points used in these measurements were the same as those foi which the E_c and R_c lines are shown in Fig. 13. It will be seen that the open-circuit rectified E.M.F. is considerably greater than the no-load rectified E.M.F., as was predicted earlier. The curves would

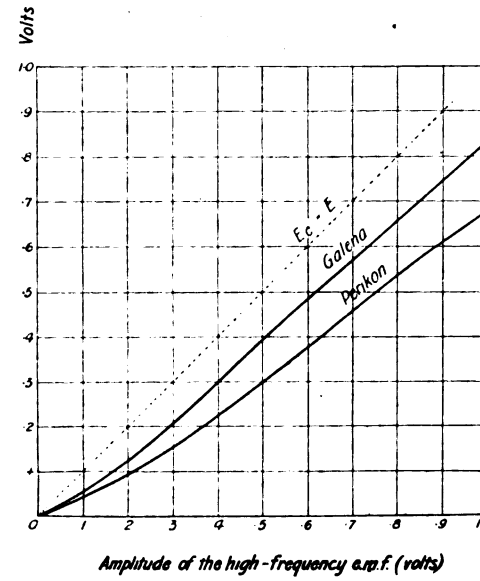

Fig. 25. *Showing V_0 for various values of input voltage, in the case of infinite load.*

suggest that galena is likely to be a far more sensitive open-circuit rectifier than perikon, but it must not be forgotten that the damping introduced by the latter into an oscillatory circuit is likely to be considerably less than that associated with the former, so that in practice it is probable that perikon is the more suitable detector for use in this way, especially as it has the additional advantage of comparative stability of contact.

* We have taken the liberty of adding Fig. 25*a* (see next page), showing E_c/E in terms of E, the values being derived from Fig. 25.—Ed. E.W. & W.E.

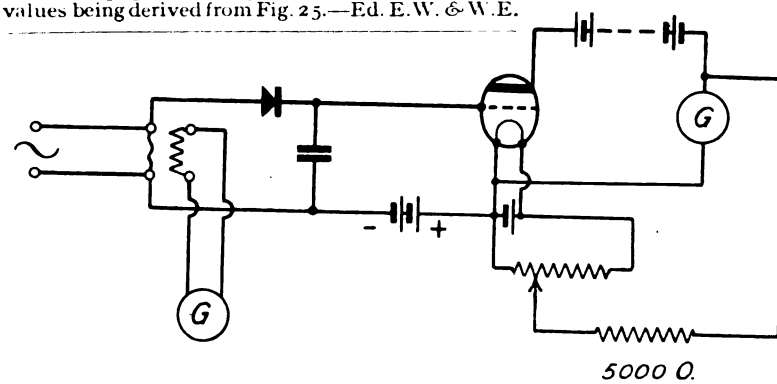

Fig. 24. *To ascertain the magnitude of V_0 in Fig. 23, the circuit was as shown.*

7. The Rectification of a Modulated E.M.F.

Up to the present point the rectification of continuous waves only has been considered. This is, as it were, the fundamental case, and the other and more practically important applications of rectification

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will be found to be based on the foregoing analysis.

An application of particular interest at the present time is that of speech- or music-modulated continuous waves. For the purposes of analysis, an E.M.F. of this character will be represented by

$$e=(E+m)\sin\omega t \quad .. \quad (7\cdot1)$$

where m is some audio-frequency alternation of more or less variable character

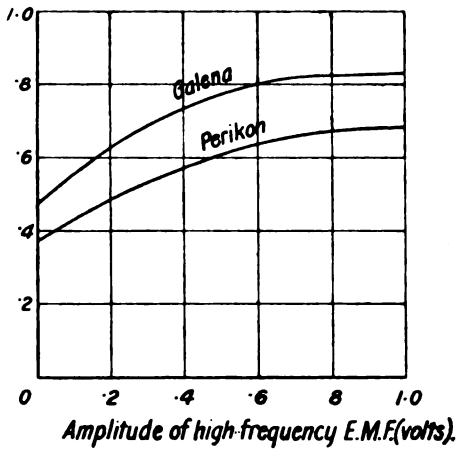

Fig. 25a. *Derived from Fig. 25, this shows the actual ratio of input to output voltage.*

and complex wave form. To fix ideas we will assume that for an appreciable period of time the fundamental frequency and wave form of m remain constant, the former being $n/2\pi$. Also, for simplicity, we will consider first the case in which there is no load in series with the rectifier. Under this condition, the equation

$$i_0=F(E) \quad .. \quad .. \quad (7\cdot2)$$

which refers to the rectification of a continuous wave, will be replaced by

$$i_0+i_m=F(E+m) \quad .. \quad (7\cdot3)$$

i_m being a current of the same fundamental frequency as m and of wave form as yet unspecified. Since $F(E)$ is in all practical cases a finite and continuous function of E, we have, by Taylor's theorem,

$$i_0+i_m=F(E)+mF'(E)+\frac{m^2}{2!}F''(E)+\ldots$$
$$\ldots+\frac{m^n}{n!}F^n(E)+\ldots \quad (7\cdot4)$$

In practice m will be small compared with e. In fact, putting M and E for the corresponding amplitudes, M/E will rarely exceed about 15 per cent. in commercial telephony or broadcasting. Further, the curvature of the $F(E)$ line will generally be small. With a good crystal detector, operating at amplitudes of ·4 volts or more, the curvature will be quite negligible. It follows from the above considerations that in the right hand side of equation (7·4), only the first two terms will be really significant, i.e.,

$$i_0+i_m=F(E)+mF'(E) \quad .. \quad (7\cdot5)$$

whence, in virtue of a well-known principle,

$$i_0=F(E) \quad .. \quad .. \quad (7\cdot6)$$
$$i_m=mF'(E) \quad .. \quad (7\cdot7)$$

From these equations three deductions can be made.

(*a*) The continuous component of the rectified current is not affected by the modulation. It should be noted that this will not be the case if the third and subsequent terms of equation (7·4) are appreciable, for we should have

$$i_0=F(E)+\frac{M^2}{4}F''(E) \quad .. \quad (7\cdot8)$$

It can be shown experimentally that in practice $M^2/4\ F''(E)$ is negligible compared with $F(E)$. The arrangement is as shown in Fig. 26. Briefly, it consists of the measurement of i_0 by means of a sensitive galvanometer. It will be found, on tuning the aerial to a broadcast transmission, that the modulation produces no effect on the magnitude of the continuous component.

(*b*) The second deduction is that under the assumed conditions the modulation frequency current will be a faithful reproduction of the modulation m. The important requirement for purity of reproduction is seen to be the straightness of the $F(E)$ line over the range of variation m. In this respect the average crystal detector is very satisfactory indeed.

(*c*) The third point to notice is that the sensitivity of a detector from the present point of view will depend chiefly on the slope of the $F(E)$ line, or, as it may be termed, the rectification characteristic at no load.

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The above analysis can be illustrated by reference to an actual rectification characteristic as shown in Fig. 27. The variation of the amplitude E over the range m produces a variation MM' on the $F(E)$ line, and a consequent variation AA' in i_0. The omission of all terms after the second in equation (7·4) is equivalent to stating that MM' is sensibly a straight line.

8. The Effect of a Modulation Load.

It is now necessary to consider the modifications introduced by the presence of telephones or any other modulation frequency load in series with the rectifier. The case is that illustrated in Fig. 6, except that the load must now be regarded as a general impedance whose D.C. resistance is R, and whose impedance at a frequency $n/2\pi$ is of magnitude Z_n and phase angle θ_n. In operator notation

$$\dot{Z}_n = R_n + jX_n \quad \ldots \quad \ldots \quad \ldots \quad (8.1)$$

where

$$Z_n^2 = R_n^2 + X_n^2 \quad \ldots \quad \ldots \quad (8.2)$$

and

$$X_n/R_n = \tan\theta \ldots \quad \ldots \quad \ldots \quad (8.3)$$

The equations of para. 4 will still apply to the present case, with the following modifications. In place of i_0 we shall have i_0+i_m; in place of v_0 we shall have v_0+v_m, v_m being the back E.M.F. due to the modulation-frequency currents flowing in the load; in place of the constant amplitude

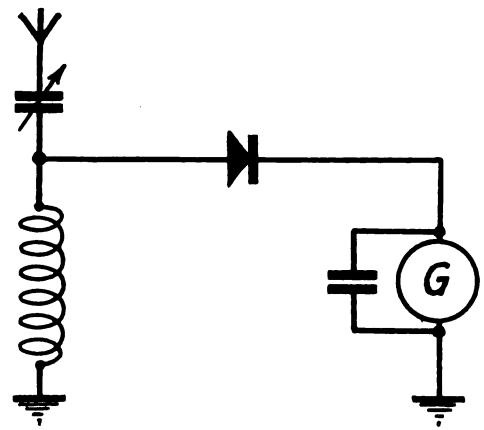

Fig. 26. *To check the conclusion that the modulation should not affect rectification of the carrier wave, this circuit was used.*

E we shall have the modulated amplitude $E+m$. The fundamental equation therefore becomes, making the same assumptions as in the no-load case,

$$i_0+i_m = F(E+m) - (v_0+v_m)F_1(E+m) + \frac{(v_0+v_m)^2}{2!}F_2(E+m) - \ldots$$
$$\ldots + (-1)^n\frac{(v_0+v_m)^n}{n!}F_n(E+m) + \ldots \quad (8\cdot4)$$

$$= F(E) + mF'(E) - (v_0+v_m)\left[F_1(E)+mF_1'(E)\right] + \frac{(v_0+v_m)^2}{2!}\left[F_2(E)+mF_2'(E)\right] - \ldots$$
$$\ldots + (-1)^n\frac{(v_0+v_m)^n}{n!}\left[F_n(E)+mF_n'(E)\right] - \ldots \quad (8\cdot5)$$

i.e.,

$$i_0+i_m = \left[F(E) - v_0F_1(E) + \frac{v_0^2}{2!}F_2(E) - \ldots + (-1)^n\frac{v_0^n}{n!}F_n(E) + \ldots\right]$$
$$+m\left[F'(E) - v_0F_1'(E) + \frac{v_0^2}{2!}F_2'(E) - \ldots + (-1)^n\frac{v_0^n}{n!}F_n'(E) + \ldots\right]$$
$$-v_m\left[F_1(E) - v_0F_2(E) + \frac{v_0^2}{2!}F_3(E) - \ldots + (-1)^n\frac{v_0^n}{n!}F_{(n+1)}(E) + \ldots\right]$$
$$+(\text{terms in } v_m^2,\ v_0v_m^2,\ v_m^3,\ \textit{etc.}) \quad \ldots \quad \ldots \quad \ldots \quad (8\cdot6)$$

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In practice the last and subsequent groups of terms will be quite negligible by comparison with the first three groups. As far as the continuous component is concerned, this can be confirmed experimentally by inserting a modulation frequency load in the circuit shown in Fig. 26. It will be found that, as before, the continuous component is not appreciably affected by the modulation.

From equation (8·6) we have

$$i_0 = F(E) - v_0 F_1(E) + \frac{v_0^2}{2} F_2(E) - \ldots + (-1)^n \frac{v_0^n}{n!} F_n(E) + \ldots \quad .. \quad (8\cdot7)$$

and

$$i_m = m\left[F'(E) - v_0 F_1'(E) + \frac{v_0^2}{2!} F_2'(E) - \ldots + (-1)^n \frac{v_0^n}{n!} F_n'(E) + \ldots\right]$$

$$-v_m\left[F_1(E) - v_0 F_2(E) + \frac{v_0^2}{2!} F_3(E) - \ldots + (-1)^n \frac{v_0^n}{n!} F_{(n+1)}(E) + \ldots\right] \quad (8\cdot8)$$

For abbreviation, we will put

$$F'(E) - v_0 F_1'(E) + \frac{v_0^2}{2!} F_2'(E) - \ldots + (-1)^n \frac{v_0^n}{n!} F_n'(E) + \ldots = K_c \quad .. \quad (8\cdot9)$$

and

$$F_1(E) - v_0 F_2(E) + \frac{v_0^2}{2!} F_3(E) - \ldots + (-1)^n \frac{v_0^n}{n!} F_{(n+1)}(E) + \ldots = \frac{1}{R_{cm}} \quad .. \quad (8\cdot10)$$

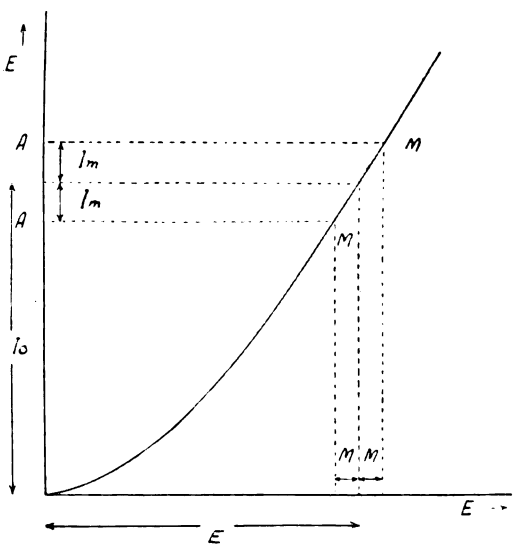

Fig. 27. *If the detector characteristic is straight between M and M, there will be no distortion in rectifying telephony.*

It should be noted that R_{cm} and K_c depend only on the characteristic of the detector, the amplitude, and the D.C. load, and are independent of the character of the modulation and its amplitude. Using these abbreviations, equation (8·8) is seen to take the very simple form

$$i_m = K_c m - \frac{v_m}{R_{cm}} \quad .. \quad .. \quad (8\cdot11)$$

From this point, having shown that the modulation frequency equation contains no important terms involving squares or products of m and v_m, it will be permissible to simplify the analysis by considering a single pure tone modulation only, since the general case will only be the sum of the separate harmonic components. We will assume therefore that

$$m = M \sin nt \quad .. \quad .. \quad (8\cdot12)$$

By rearrangement of terms, and using vector notation, equation (8.11) becomes

$$\mathbf{I}_n = \frac{K_c R_{cm} \mathbf{M}}{\dot{Z}_n + R_{cm}} \quad .. \quad .. \quad (8\cdot13)$$

The physical significance of the various terms is now apparent. The term $K_c R_{cm} \mathbf{M}$ is effectively a modulation frequency E.M.F. It is associated with an internal resistance R_{cm}, and acts in a circuit of which the impedance is $\dot{Z}_n$.

In any case in which the exact form of the function $f(e)$ is known, the evaluation of the above quantities presents no difficulty. For instance, an ordinary crystal detector,

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operating at amplitudes up to about 100 millivolts, can be represented very closely by

$$i=a_1e+a_2e^2+a_3e^3+a_4e^4 \quad .. \quad (8\cdot14)$$

For this characteristic we have, as shown in the earlier part of the paper,

$$F(E)=\frac{1}{2}a_2E^2+\frac{3}{8}a_4E^4 \quad .. \quad (8\cdot15)$$

$$F_1(E)=a_1+\frac{3}{2}a_3E^2 \quad .. \quad (8\cdot16)$$

$$F_2(E)=2a_2+6a_4E^2 \quad .. \quad (8\cdot17)$$

$$F_3(E)=6a_3 \quad .. \quad (8\cdot18)$$

$$F_4(E)=2-a_4 \quad .. \quad (8\cdot19)$$

$$F'(E)=a_2E+\frac{3}{2}a_4E^3 \quad .. \quad (8\cdot20)$$

$$F_1'(E)=3a_3E \quad .. \quad (8\cdot21)$$

$$F_2'(E)=12a_4E \quad .. \quad (8\cdot22)$$

$$F_3'(E)=F_4'(E)=0 \quad .. \quad (8\cdot23)$$

Therefore

$$K_c=\left(a_2E+\frac{3}{2}a_4E^3\right)-3a_3Ev_0+6a_4Ev_0^2 \quad (8\cdot24)$$

and

$$\frac{1}{R_{cm}}=\left(a_1+\frac{3}{2}a_3E^2\right)-$$
$$-(2a_2+6a_4E^2)v_0+3a_3v_0^2-4a_4v_0^3 \quad (8\cdot25)$$

For the same characteristic the values of v_0 for given values of R can be determined by the reversed method of solution described in para. 5, so that the evaluation can be carried out completely. The process is illustrated below.

In the numerous practical cases in which the shape of the characteristic cannot be specified in mathematical form, the quantities K_c and R_{cm} can be determined in the following simple manner. It will be assumed that we have a family of curves giving i_0 in terms of E for various values of R. From such curves can be obtained the values of $\delta i_0/\delta E$ for a constant value of R, and $\delta i_0/\delta v_0$ for a constant value of E. Now from equation (4·10) for i_0

$$\left(\frac{\delta i_0}{\delta E}\right)_R=\left[F'(E)-v_0F_1'(E)+\frac{v_0^2}{2!}F_2'(E)\right.$$
$$\left.-\ldots+(-1)^n\frac{v_0^n}{n!}F_n'(E)+\ldots\right]-$$
$$-\left(\frac{\delta v_0}{\delta E}\right)_R\left[F_1(E)-v_0F_2(E)+\frac{v_0^2}{2!}F_3(E)\right.$$
$$\left.-\ldots+(-1)^n\frac{v_0^n}{n!}F_{(n+1)}(E)+\ldots\right] \quad (8\cdot26)$$

or

$$\left(\frac{\delta i_0}{\delta E}\right)_R=K_c-\left(\frac{\delta v_0}{\delta E}\right)_R\frac{1}{R_{cm}} \quad (8\cdot27)$$

whence, by re-arrangement of terms,

$$\left(\frac{\delta i_0}{\delta E}\right)_R=\frac{R_{cm}K_c}{R_{cm}+R} \quad .. \quad (8\cdot28)$$

Further, from equation (8·7)

$$-\left(\frac{\delta i_0}{\delta v_0}\right)_E=F_1(E)-v_0F_2(E)+\frac{v_0^2}{2!}F_3(E)-$$
$$\ldots+(-1)^n\frac{v_0^n}{n!}F_{(n+1)}(E)+\ldots \quad (8\cdot29)$$
$$=\frac{1}{R_{cm}} \quad .. \quad .. \quad (8\cdot30)$$

In either case, therefore, the determination of the quantities K_c and R_{cm} is a comparatively simple matter.

THE STRENGTH OF SIGNALS.

According to the report lately issued for last year by the Committee of the Privy Council for Scientific and Industrial Research, the apparatus developed at the National Physical Laboratory for the measurement of the strength of received wireless signals has been completed, and sets of apparatus erected at four places in Great Britain.

The strength of the signals sent out, under the auspices of the International Union, from European transmitting stations, is being measured each day. An endeavour is being made through the British National Committee of the Union to arrange for an increase in the number of transmitting signals suitable for measurement.

AUSTRIAN AMATEURS.

Austria, like several other European countries, is just realising that the wireless amateur should be encouraged and not hindered. As a result of the revised regulations, it is proposed to form an Austrian Club for Transmitting Amateurs, and the organisers wish to have the addresses of English amateurs willing to conduct tests with their members. British amateur transmitters who have a knowledge of German or Esperanto and who would be pleased to be put into communication with Austrian amateurs, are requested to write to the Hon. Secretary, Internacia Radio-Asocio, 17, Chatsworth Road, London, E.5.

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Constructing a Suspended Moving Coil Galvanometer.

By R. W. Hardisty, Student I.E.E. (5MD). **[621·374·4**

"I always say that if you can measure that of which you speak, and express it by a number, you know something of your subject; if you cannot, your knowledge is meagre and unsatisfactory."—LORD KELVIN.

IT is proposed to describe in this article how a galvanometer reading to 0·1 or 0·01 microamp may be made with a lathe and a few metal tools. Detailed dimensions are not specified, as these will alter in individual cases, but the difficulties encountered, and the means of overcoming them, have been considered as of greater importance.

The lathe employed was a Drummond 4 in. "A" type model-maker's lathe. Readers acquainted with this machine will, no doubt, understand any references made to it.

The Magnet.

This was obtained from a large assortment on the scrap-heap of a local garage. The writer was told that it was originally a Bosch magneto magnet, at any rate it is of exceptionally good quality steel. It is important to remember to look for a magnet with suitable fixing holes for the pole-pieces, as these cannot be afterwards drilled as the metal is dead hard.

The Pole Pieces.

These were made of wrought iron obtained from the local foundry. They were obtained in two pieces and bored with a boring bar specially constructed for the purpose.

It will be remembered that the Drummond is supplied without back gears, this renders the work exceedingly heavy. A slow speed on the cone-pulley was employed, however, and the magnet clamped, with pole pieces ready fitted, on to the cross-slide as shown in Fig. 1.

It should be noted that the sensitivity of the instrument will depend upon the ratio of the length to the breadth of the coil, for with a broad and short tunnel the lines of magnetic force will not only be less crowded together but also the end effects (as shown in the sketch) will be appreciable so that deflections for the same current will be different in different parts of the scale.

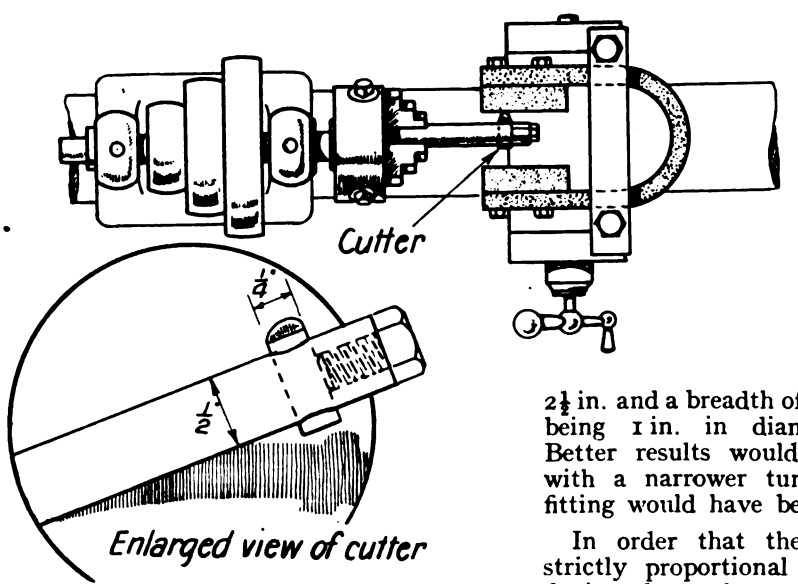

Fig. 1.

It was found in this case that a length of 2½ in. and a breadth of ¾ in.—⅞ in., the tunnel being 1 in. in diameter, was sufficient. Better results would have been obtained with a narrower tunnel, but very careful fitting would have been necessary.

In order that the deflections shall be strictly proportional to the currents producing them, the tunnel must be provided

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with a central core (see Fig. 2). This was made of wrought iron bar $\frac{1}{2}$ in. in diameter.

The central core is fixed to a brass back plate by two 4 BA screws and kept central by two distance pieces of $\frac{1}{4}$ in. brass rod.

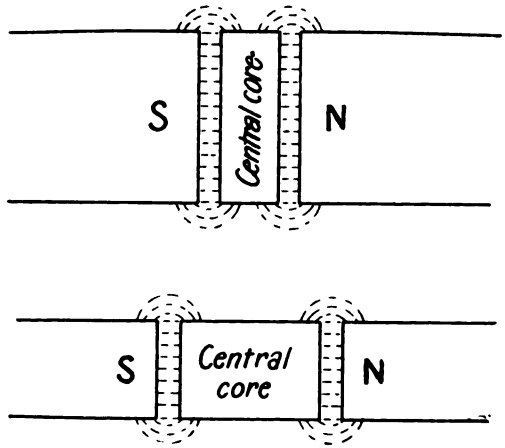

Fig. 2.

In the writer's instrument the whole magnet is supported by a brass pillar $\frac{5}{8}$ in. in diameter, which also carries the suspension arrangement.

The Base.

This is of brass, cast by the local foundry. A pattern was made in elm (this is not an ideal wood for the purpose, but it was the only wood available. A closer grained wood is preferable). As can be seen from the photograph, the base is made with a flange to support the outer case.

For the benefit of those who have not before made patterns for castings, the edges of the flange must be relieved so that the pattern may be drawn out of the mould without disturbing the sand.

When the casting is delivered it is covered with a very hard scale. This must be removed, and the only way to get it off is to dig the tool right under the scale, and take a heavy cut. Here difficulties arose, as the radius of the base was considerable, hence the peripheral speed was really far too great for the job. However, with patience and repeated sharpening of the tool, the scale was removed from the parts that would be visible in the finished state.

The base is next drilled with three holes for the levelling screws, and these holes are tapped. A large hole is required for the main brass pillar, two for the terminals, which are bushed with ebonite, and two more, to enable the leads from the terminals to be brought through.

The Coil.

A piece of $\frac{1}{4}$ in. ebonite sheet is cut and filed till it is just slightly longer than the central iron core. The edges of this piece of ebonite should be filed to a slight bevel (for reasons which will be given later) and the corners carefully rounded off. Two more pieces of $\frac{1}{8}$ in. ebonite are now cut, larger than the above by $\frac{3}{16}$ in. all round, and screwed to it on either side. The coil former is now ready for winding.

The coils at present used are two. One is dead-beat, the other ballistic. The ballistic coil was constructed first. 250 turns of No. 40 S.W.G. enamelled wire were used in both cases. The gauge of wire is really immaterial, so long as the coil is light, but the writer had a large quantity of this wire, and it is easy to handle.

It is, of course, advantageous that the winding should be as neat as possible, so that a large number of turns may be put into a small space. A slight tension only should be put on the wire while winding.

The ends of the winding are brought out to opposite ends of the coil. One of these is soldered to the mirror support (described below), the other is soldered to a piece of 47 S.W.G. which is in turn soldered to a stiff piece of wire brought through an ebonite sleeve from one of the terminals in the front.

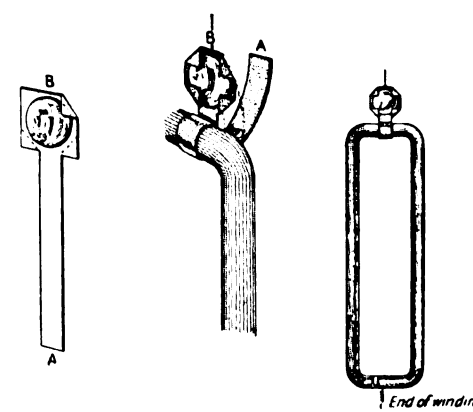

Fig. 3.

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After winding, the whole former is dipped in a tin of molten paraffin wax. When this has set, an attempt may be made to remove the coil from the former, an operation which is facilitated by having the ebonite on a bevel. If any difficulty is experienced in removing the coil, it will be found that by pressing in the winding on the longer sides, the coil will come off easily in most cases. The finished coil is shown in Fig. 3.

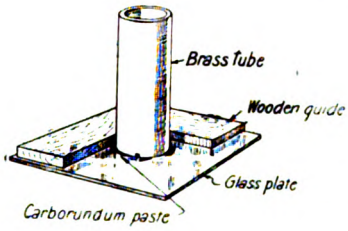

Fig. 4.

The coil is now tested for continuity, and a piece of copper foil cut as shown in the sketch, Fig. 3. This will be required to bind the coil and support the mirror, and to it the suspending wire will be soldered.

The piece of foil should be bent round the winding and soldered to itself. One end of the winding is soldered to the foil, and finally the suspending wire soldered on. (Fig. 3 B).

"Dead-beat" coils are often wound on copper formers, or several turns of wire—apart from the winding—may be put on and short-circuited. The currents induced in these turns, due to their motion with the coil, will react on the field of the permanent magnet and rapidly bring the coil to rest. The author has so far tried one "dead-beat" coil with only one short-circuited turn, but its behaviour has brought home to him the fact that the damping action of these turns is proportional to the percentage which they form of the total number in the actual coil (in this case 250). Ten or twenty turns would be likely to produce better damping.

The mirror is a microscope cover-glass, silvered by the glass works at a cost of 6d. It is secured by bending round the corners of the copper foil, and not stuck on.

Plane or concave mirrors (1 metre focus) can be obtained from scientific instrument makers for 2s. 6d., but owing to the liability to breakage when mounting the above method is probably cheaper.

The Suspension.

The equation for the torsional force on a wire of radius r twisted through an angle ϕ per unit length, the coefficient of rigidity of the material being n, is given by

$$\tau = \tfrac{1}{2} n \phi r^4 \pi$$

this force is, of course, balanced by the couple due to the current in the coil. It is therefore obvious that r must be made as small as possible.

In the case of this instrument, the suspending wire is of 47 S.W.G. Another piece of the same wire is used for the bottom lead to the coil. This, of course, need not be taut.

The Suspension Adjustment.

It is necessary in an instrument of this kind that the point of suspension should be adjustable in three directions.

The top of the brass pillar is drilled $\frac{1}{4}$ in. for a depth of about $\frac{1}{2}$ in. A 2 BA screw is tapped from the side into this hole.

A piece of ebonite rod is next turned up and a piece of $\frac{1}{4}$ in. brass rod is inserted in a hole at the end—a driving fit. About $\frac{1}{2}$ in.

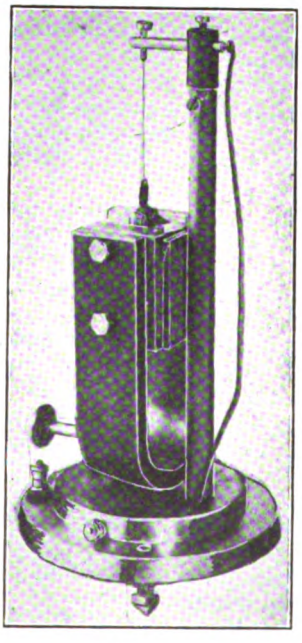

Fig. 5.

Fig. 6.

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of this projects from the ebonite and fits the hole in the pillar. This provides for adjustment in the horizontal plane.

Another ¼ in. hole is drilled through the ebonite to support the brass rod carrying the suspending pin, and a second 2 BA is tapped into the top to clamp the forward and back adjustment. Finally a small pin, to which the suspending wire is attached, is arranged a push fit in the ¼ in. brass rod as shown in the photograph.

The suspension release consists of a T-shaped brass (not steel!) strip which is secured to the pole pieces by two set screws and carries a hole in the opposite end to which a string is attached. This string is wound on a winch arrangement in the front of the base of the instrument.

The main body of the case is of brass tube. Another piece of tube was procured 1¾ in. in diameter. A hole was next cut in the main tube to accommodate this (by drilling out a ring of holes, and filing to shape). A flange was constructed out of sheet brass, carefully bent to fit the curvature of the main tube, filed to fit the side tube, and finally soldered to the latter. The flange was then drilled for two screws to fix it to the main tube. Another flange is soldered on to the front of the side tube to support the glass window.

The glass window was cut out of a photographic plate by grinding out with a piece of tube the same size as the side tube, fed with carborundum compound on its end. Fig. 4 illustrates this method of cutting the glass. The circular piece of glass so formed was carefully ground on an emery wheel till it fitted the brass side tube. It was then secured inside by a ring of steel wire in the usual way.

The top of the case—as may be seen from the photograph—is of sheet brass, arranged to fit on to the main body with a bayonet catch and two screws.

The photographs (Figs. 5, 6 and 7) show the complete instrument with and without the brass case.

The Lamp and Scale.

By far the most convenient lamp for use with reflecting instruments of this kind employs a 6-volt 6 c.p. automobile bulb. The lamp, which is not shown in the photograph, was made from a piece of 1¾ in. brass tubing. A lens was provided to fit the front, having a focal length of about 3 inches. (This lens was taken from an old bicycle lamp, and is consequently not corrected for chromatic aberration, etc.!).

A piece of fine wire is fixed perpendicularly at one of the unit planes (found by trial) so that it casts an image of its own size on the scale.

The whole lamp tube is supported by a U-piece at its point of balance, and can be rotated in two planes.

The scale is of paper, obtainable from Messrs. W. G. Pye & Co., Cambridge, for 6d.

General Performance.

Without any shunt the instrument reads 0·1 microamp easily. For ranges 0–1 milliamp

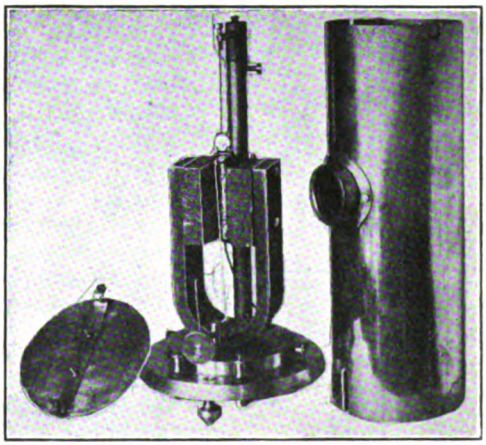

Fig. 7.

a shunt of about ½–1 ohm is used. (At present the writer has not been able to work out the shunts exactly, and this one was assembled at a moment's notice for some experimental work.)

The author hopes that this article has shown that such a galvanometer is well within the constructional power of the amateur with a lathe. The time and labour taken to construct the instrument has, in his opinion, been well repaid after only a few weeks' use. The base cost 10s. to cast; the only other item of importance is the case—about 7s. The total cost is under £2.

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The Perfect Set.

Part VII: More about H.F. Amplification. [R132

In this instalment we consider the details of H.F. Coupling.

IN our last article, we opened up the question of H.F. amplification, and showed some of the points which cause such a radical difference in the design and performance of H.F. and L.F. amplifiers.

Perhaps the most important conclusion there drawn was that, owing to the "Miller effect"—the dependance of a valve's input impedance on the output load—we could not consider each part of the amplifier as a separate unit. It is therefore not practicable to do as we did for L.F. work: deal with the valve and the coupling as two quite separate things.

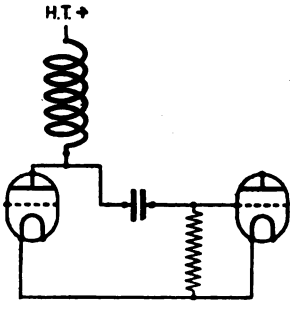

Fig. 1.

We can, however, begin by looking at the conditions of valve operation; and we can lay down the same three main requirements, for maximum efficiency, as in the case of L.F. work:

(1) A length of "straight" characteristic sufficient to accommodate the grid swing.

(2) No grid current.

(3) Operation entirely on the straight part of the curve.

But in practice the effect produced by a departure from these conditions is very much less for H.F. As regards (1), the grid swing in most H.F. amplifiers is so small that any ordinary valve will handle it easily. The minimum filament heat is rather that below which the slope of the valve curves is too small rather than that below which the length of curve is too short. If by any chance we do fail to get a long enough curve, we lose some amplification, but the possibility is remote.

Again, as regards (2). The troubles produced in L.F. work by grid current are two: first, low input impedance, leading to bad amplification, and second, *irregular* input impedance leading to distortion (see earlier instalments). But in the H.F. stages, the input impedance is already low, very likely as low as 20 000 ohms; and the effect of a positive grid is more or less that of putting, say, 100 000 ohms across it: it will not make a lot of difference.

Point (3) is not now necessary to avoid L.F. distortion, but it has quite an important effect on amplification. The straight part of the valve characteristic is also the steepest part, and gives the best amplification.

Couplings.

Now as regards the coupling. There is a greater variety in H.F. than in L.F. circuits; not so much on account of the coupling itself as for the reason that various special steps are often taken to try and combine stability with high amplification.

Such couplings fall naturally into two main classes. There are those in which an attempt is made to balance out or otherwise compensate for the Miller effect; and there are those in which one simply tries to prevent such capacity effects from causing instability. We shall deal first with the latter.

In the days when amateurs devoted much attention to long-wave telegraphy, the resistance-coupled amplifier was considerably used. But for reasons shown in our last instalment, it is extremely difficult to get good amplification at short wave-lengths, and this form of coupling is now seldom used for H.F. work.

The choke amplifier has been used to a certain extent, but for short-wave work there are difficulties in the design of the choke, which must have high inductance and low self-capacity. It may be of interest, however, to note a design patented by Miller about a year ago, which was claimed to be effective for all radio frequencies, although no tuning is involved.

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The circuit is a quite normal one, as shown in Fig. 1, the point being in the design of the choke. This consists of a slab coil of fine wire, shown natural size in Fig. 2, and containing about 5 000 turns. The inductance is of the order of 500 000μH, and the self-capacity is about 2·5$\mu\mu$F. This choke has a natural frequency of about 150kC (2 000 metres), and at this point behaves like a resistance of 2 megohms. On either side of resonance the impedance gradually falls off; but at 20 000 metres it is still 45 000 ohms, and as low as 200 metres it is 40 000 ohms. At broadcast wave-lengths it would be about 80 000.

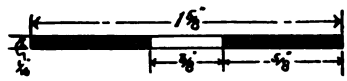

Fig. 2.

It will be noted that we cannot regard a choke as a pure inductance, but that we must take account of the fact that it has a natural tuned wave-length. This fact led naturally to the use of a tuned choke, intended to be operated always at its resonant frequency—in fact, the tuned anode circuit. When this is tuned it becomes (for H.F. currents of this frequency) a high resistance; but we have already given reasons why it is not usually exactly tuned.

A third form of coupling often used is the transformer, and it is quite common for this to be considered an entirely different type of circuit from the "tuned anode." But the kind of transformer which is probably the best is really extremely closely akin to the tuned anode circuit.

Fig. 3, for example, shows a typical "tuned anode" coupling. The theory is that since the rejector circuit A offers a high impedance to H.F. currents, there will be a fairly high H.F. voltage across it. One side of it is connected through condenser B, to the next grid, and the other through condenser C to the filament. As B and C offer only a low impedance to H.F., the H.F. voltage across A will be applied to the grid. Now suppose, as in Fig. 4, that we wind the coil with two windings, and connect anode to one and the next grid to the other, the conditions are identical. As the two windings have equal turns, there will be equal voltages across them, for the back E.M.F. in the first coil, caused by its self-inductance will be the same as the E.M.F. in the second, caused by the mutual inductance, and the same voltage as before will be applied to the second grid. In practice there will be a slight difference, for there will be a few lines of force that do not cut both windings; the effect is a very slight drop in the grid voltage. Note that any variation of the condenser alters the current in the first winding, hence alters the magnetic field, and therefore the output voltage: in other words the condenser tunes both windings.

Now it would be just as easy to connect the upper end of the second winding direct to the filament instead of via condenser C. This leads to Fig. 5. But now the grid circuit is no longer connected to the + side of the anode battery, as it was before, hence the grid condenser is not necessary (unless, of course, valve No. 2 is a detector). We can therefore cut out B, and as a natural result can abolish the grid-leak, which (where this valve is not a detector) is only inserted because otherwise B would give an isolated grid. Making this change, and turning A upside down for simplicity in drawing, we get Fig. 6. This is a typical transformer coupling, and we therefore see that a transformer coupling, using a tight-coupled 1-to-1 transformer with tuned primary, is in its main action almost identical with tuned anode. What points of difference arise?

The tuned anode needs only one winding, but necessitates a leak and condenser.

The transformer needs two windings, but

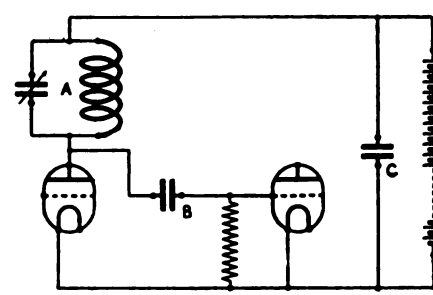

Fig. 3.

no leak nor condenser, and gives us the chance to use a ratio different from 1 to 1 if we desire. There is obviously little to choose as regards expense or space occupied.

Now as to their merits. It is obvious that if the second valve, as is often the case, is to be a grid current detector, the tuned anode circuit has the advantage of simplicity, and it will probably be considered that the possibility of a gain by having a different

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turns ratio is not sufficient to warrant the extra trouble. It is appropriate to consider at this point the question as to what is the correct turns ratio. This depends on how closely the two windings are coupled and on the relative impedances of the input and output circuits of the transformer—in this case that of the anode circuit of the first valve and the grid circuit of the second. As a first approximation to the required ratio divide the grid impedance by the anode impedance, and take the square root of the result.

But we have already shown that the grid impedance is a very variable quantity; so that one cannot say very definitely what the best ratio is: it will depend on the valves, the wave-length, and the anode circuit of the second valve. The writer's own experience over broadcast ranges indicates that a step up of 1 to $1\frac{1}{2}$ or 1 to 2 is distinctly

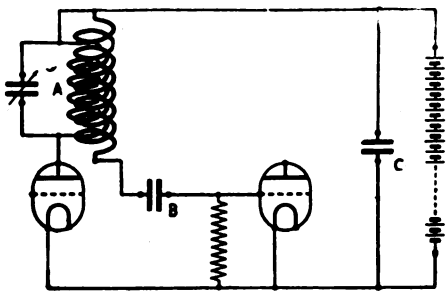

Fig. 4.

superior to 1 to 1; but if it is desired to try H.F. on the short waves of 50 to 100 metres, probably 1 to 1 or even a step down of $1\frac{1}{2}$ to 1 would do better.

If, on the other hand, the coupling is not to be followed by a grid detector, the advantage is distinctly with the transformer. Firstly we have the power to alter the tunes ratio, as already explained; secondly, we do away with the grid condenser and leak. This is an advantage (apart from the saving in components) because the leak and condenser can never help amplification, and in some cases hinder it quite a lot. For if at any time a grid current flows, it will charge up the condenser, just as in a rectifying valve; and this charge may last quite a long time ($\frac{1}{1000}$ second is a long time in radio-frequency work). During this period the valve is operating with its grid considerably more negative than normal, and it may easily happen that it will not, under these conditions, be amplifying nearly as well as it might.

In the previous comparison between tuned anode and transformer coupling, we have been treating of a transformer distinguished

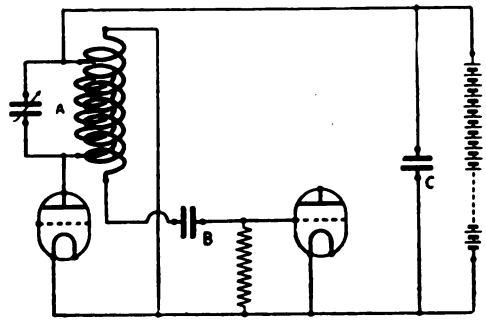

Fig. 5.

by two features: it is close-coupled, and one winding has a condenser across it. It must be realised that there are other types of transformer.

On the one hand, it is quite possible to use a loose-coupled transformer, as in Fig. 7. This is a highly efficient coupling here as it is elsewhere. It has, however, the disadvantage (often fatal) of needing three adjustments: the two condensers and the coupling. Its selectivity is, of course, extreme, and it is really not a practical proposition for ordinary work, though for special purposes it is unrivalled.

At the other extreme, we have the close-coupled transformer with no tuning arrangement at all. This, of course, has its own

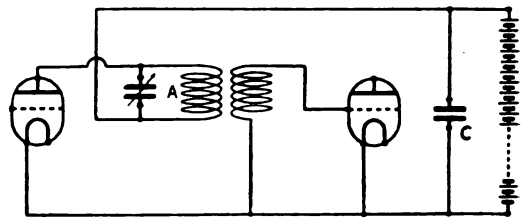

Fig. 6.

natural wave-length, due to its self-capacity, and if it is made in the usual way, it is fairly sharp in its tuning. This would necessitate having a large set of interchangeable transformers, so special steps are usually taken to make each transformer cover a wider band. A favourite method is to wind with resistance

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wire. Or we may arrange the windings with tappings, and provide a switch—there are several such instruments on the market.

But for work with one, two, or three stages, our own opinion is that if an untuned or flat-tuned set is wanted the Miller choke already described is the best; while if we want selectivity the close-coupled tuned transformer is by far superior to other couplings. Further, we much prefer plug-in

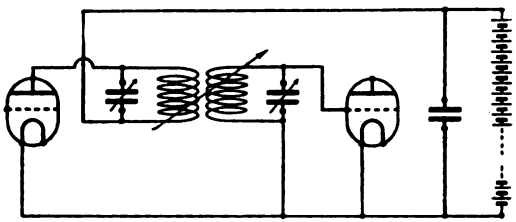

Fig. 7.

transformers to the tapped type, and in our own work we have finally settled on two types of transformer which have given every satisfaction.

The type which we will describe first is the less efficient, but can be made for any wave-length.

It simply possesses two windings, wound one over the other in the same slot. The former may be either an empty ebonite one of the usual one-slot type (various firms will supply these empty formers), or it can be built up of two large thin and one small thick ebonite discs: some of our transformers are built up on waxed cardboard formers, and appear quite efficient. The one important point is to keep down the self-capacity of each winding and the mutual capacity between the two. With this object in view, the windings are deep and narrow: we make it a rule that in no case is a winding less deep than 1½ times its width, and prefer them deeper. Between the two windings there should be a space; in practice we wind on 20 turns or so of cotton thread.

Size of wire does not seem vitally important. We use as fine as 44 S.W.G. for long-wave transformers, but considerably larger—of the order of 32 S.W.G.—for short waves. Up to 600 metres, i.e., for windings of 50 to 100 turns or less, we often use a twin 40 S.W.G., each strand D.S.C., which seems very efficient: the two strands are joined at the ends. No effort is made to wind the wire on evenly, a "bad" criss-cross winding has somewhat the effect of a honeycomb winding in keeping down self-capacity.

The two ends which lie close to one another, the outside of the inner winding and the inside of the outer, are connected to the low-potential points: the wide-apart ends go to anode and grid. This is important. It does not seem to matter which winding, primary or secondary, is put on first.

A few actual examples are:—

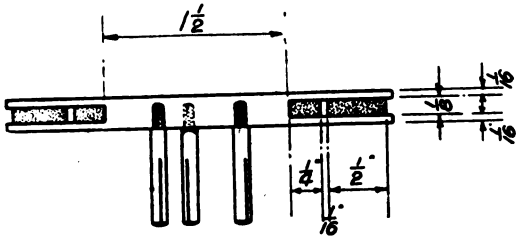

Fig. 8.

Turns.			
Prim.	Sec.	Former Diameter.	
50	100	1¾	Broadcast range, and nearly 600 metres (·000 5 condenser).
70	140	,,	about 400–800
180	300	,,	about 900-2 700
430	430	,,	about 2 000-5 000 (for this and larger ones, step-up was sacrificed to keep the size down).

A more efficient type has the disadvantage of being cumbersome at long waves. It is composed simply of a honeycomb coil cut

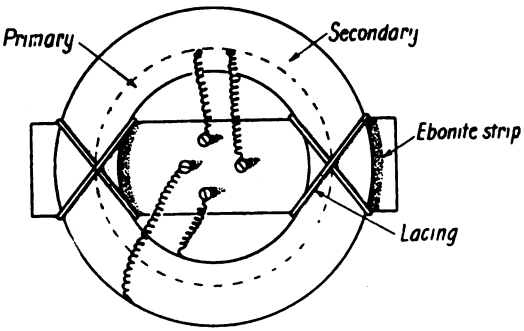

Fig. 9.

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in the middle to divide it up into two windings. Unfortunately the standard honeycomb coils as sold have too many turns per layer, and the layers are too wide, to get the "edge on" effect that we want. But anyone who can rig up a coil winder, or buy one of the little hand winders on the market, can do extremely good work.

In our own case we stole the Meccano set of our son and heir, and made a winder geared 19 to 40, which, as calculation will show, gives approximately 5 turns per layer. Coils wound on this, about ¼ in. wide, are quite efficient. For a 50 to 100 transformer we simply wind a 150-turn coil, slipping in a piece of paper as a marker under the 50th turn. When the coil is complete, the 50th turn is pulled out a little, cut, and leads soldered to the cut ends. The whole is mounted flat on a strip of ebonite carrying the contact plugs.

Now our allowance of space is used up. We must leave it to next month to discuss methods of getting stability in ordinary circuits, and special circuits designed to dodge the Miller effect altogether.

On Thermo-Junctions.

By W. Gordon Edwards, Graduate, I.E.E. **R251·2**

If the point of contact of two dissimilar metals be heated or cooled, a potential difference arises, in consequence of which an electric current flows, on completion of the circuit. Strictly speaking, it is not imperative that the metals be dissimilar, provided they are in a different molecular state and thus provide a different resistance to the passage of the heat and electricity. But since the force brought into play is proportional to the difference in the molecular states, it is customary to employ two very dissimilar metals or alloys.

Although the resulting current value is small, it becomes important in the design of sensitive electrical instruments, and the phenomenon is made use of commercially, as, in conjunction with a milli-volt-meter one has a ready means of employing it as a very sensitive and portable milli-ammeter. Duddell has incorporated the thermo-junction and movement in one instrument in his thermo-ammeter, where the ends of the moving coil are soldered to two bars of special alloy, closed by a silver plate.

There are two phenomena that should be considered, viz., the Peltier and the Thomson effects. These are respectively :—

1. The effect of the thermo-junction is perfectly reversible ; if heating the junction produces an electro-motive force, then an electro-motive force produces heating.

2. The quantity of electricity that passes across a junction has a specific heat of its own.

Neglecting the Thomson effect and considering only the Peltier :—

Let P_2=cold junction Peltier effect at an absolute temperature T_1

and P_2=hot junction Peltier effect at an absolute temperature T_2

then, by the second law of thermo-dynamics

$$\frac{P_2}{T_2}=\frac{P_1}{T_1}=\frac{\text{work done by one unit of electricity}}{\text{difference of temperatures}}$$

Calling this work done "E,"

$$E=\frac{(T_2-T_1)P_1}{T_1}$$

But $\frac{P_1}{T_1}$ is some constant "k"

therefore $E=k(T_2-T_1)$ showing that the work done depends purely on the difference of temperatures of the junctions.

This is usually summed up as

$$\int_{T_1}^{T_2} Y dt$$

where Y is the thermo-electric power of the junction in question.

If the temperature difference is dependent on I^2R and (T_2-T_1) is called γ

$$E=K_1\gamma=K_2.I^2R.$$

But with "r" as the galvanometer resistance, "i" (the current in the thermo-circuit)$=E/r$, and substituting for E from the above equation

$$i=\frac{K_2I^2R}{r}$$

or

$$I=\sqrt{\frac{ir}{K_2R}}$$

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Thus, if the current in the thermo-circuit were measured directly I is proportional to $\sqrt{\gamma}$ and the galvanometer scale would be divided accordingly. As, however, is shown below, separate calibration is much more desirable.

Various Types of Junction.

Thermo-junctions of various types, with heaters of different resistances, are made for commercial use by two or three well-known firms, but if cheapness be of more importance to the experimenter than sensitivity, he would be well advised to make his own. This can be done easily provided he exercises great care and considerable patience.

The heat can be communicated to the junction by means of :—

(1) Thermal conduction, *i.e.*, actual contact,

or

(2) Radiation and convection.

In the former case, the question of insulating the junction must not be lost sight of, and there is always a small potential drop there, due to the physical impossibility of constructing the mathematical point. This impossibility creates a reversal error—further, capacity troubles arise, so method (2) is preferable although it entails sacrificing some of the sensitivity ; the form of convection currents is not constant and the instrument responds to change of position, *i.e.*, it has a different constant when on its back to when standing upright on account of the variation of convection with position. This is not so, however, in vacuum-enclosed instruments which are considerably more sensitive, as the cooling effects of convection currents and draughts are eliminated. Further, oxidation is prevented. Experiments go to show that a pressure of about ·01 mm. is best and that below this nothing is gained, in fact the sensitivity grows less. However, these errors are of but secondary import unless research or standardising work is being undertaken.

The junctions require, most of all :—

(1) High thermal E.M.F.

(2) Materials that remain physically constant.

(3) Good mechanical properties.

(4) A minimum heat capacity.

It seems generally agreed that the form of curve for all possible thermo-junctions is as shown in Fig. 1, but usually the bend is never

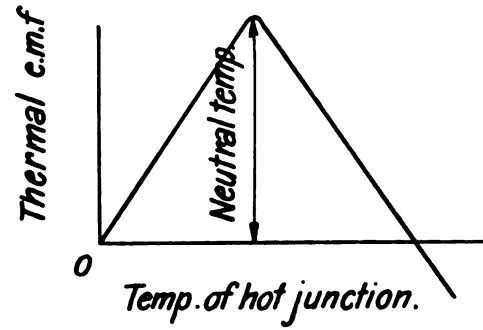

Fig. 1.

reached and it is safe to assume a straight line relationship over the ordinary working scale. The law of the curve is $E=a\theta+b\theta^2$ with one junction at $X'C$, and the neutral point is always half-way along to the reversal point.

By the law of successive materials, as long as all the components are at the same temperature, it makes no difference to the thermo-force how many there be, and this permits the use of a film of Wood's metal, because its effect disappears, being the opposite on the one element to what it is on the other.

There are no temperature errors and the junctions can be used on either direct or alternating current. The change of resistance with frequency, due to skin effect, is negligible, and it is this which makes them invaluable at radio-frequencies where a hot-wire instrument would give a reading perhaps 8 per cent. too high.

The error due to eddy-currents in any nearby wire, strip or shunt is so small that the junctions could be enclosed in an iron case just as low frequency A.C. instruments, but the inductive effect of the leads cannot be disregarded. Those carrying current to the instrument must not run parallel to any others and if a lead be turned so that it runs alongside the apparatus there is a change with frequency. The idea is, to always run the wire straight out and have no bending for some distance. At 5 cms. distance the error is of the order of 1·5 per cent. Hidden capacities must also be looked for with coupled circuits and a possible electro-static leak, but can often be cut out by a judicious arrangement of short-circuiting

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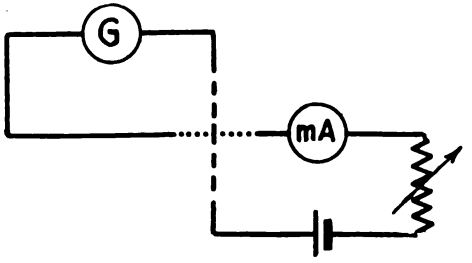
leads. It has been found that, if a temperature alteration be given to a junction in cyclic fashion, crystallisation obtains and, should this occur, erratic results are possible.

Applications of Thermo-Junctions.

Thermo-junctions are especially useful in measuring temperatures in inaccessible places, such as in a transformer, machine, coal bunker, etc., or reading at long distances and can be constructed to carry considerable current by using several wires in a squirrel-cage design. This system, however, is not



Two-way junction and connections.

to be recommended for amateur construction as the difficulty of achieving complete symmetry is very considerable.

Either the two-, or three-way type may be employed, the connections for both of which are as given. The three-way junction has a separate heating wire and the reversal error, known as the Peltier effect, is eliminated. It is easier to solder, there are two separate galvanometer circuits and we have what is practically a spare junction of equal capacity and under similar conditions to the one which may have burnt out, owing, for example, to a sudden rise in current caused by coming unexpectedly on to the resonance point.

The alternative type, already mentioned, having a separate heating wire not in contact with the junction, is the more favoured commercially, as by interchanging heaters it admits of a largely extended range, but here it is important that some means be provided so that the user can know definitely the position of the heater in relation to the junction.

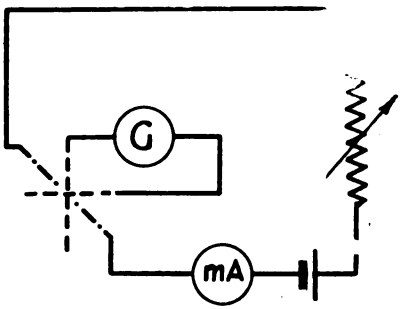
The materials employed can be, say, No. 40 S.W.G. copper (bare) and No. 47 S.W.G. Eureka (bare), or iron-constantan junctions may be utilised, but the big temperature co-efficient and magnetic effect puts them out of court for very high frequency work. Copper-constantan has a thermo-electro-motive force about 20 per cent. lower than iron-constantan, which is approximately 55 microvolts. With Manganin-constantan, however, the temperature coefficients nearly wipe out one another and this combination gives excellent results.

The composition of manganin is of the order of 84 parts copper, 4 nickel and 12 manganese, while Eureka (constantan) is 60 parts copper and 40 nickel.

The following table may be useful to the constructor in choosing his materials. It shows the thermo-E.M.F.'s against platinum in microvolts. One junction is at $0^{\circ}C$ and the current flows across the other junction from the metal with the (algebraically) smaller value.*

Metal.	—190°	100°
Aluminium	+ 390	+ 380
Bismuth	+12 300	—6 500
Copper	— 200	+ 740
Iron	— 2 900	+1 600
Lead	+ 210	+ 410
Nickel	+ 2 200	—1 640
Silver	— 140	+ 710
Tin	+ 200	+ 410
Zinc	— 120	+ 750
Constantan	—	—3 440
Manganin	—	+ 570

Bismuth wire down to ·05 mm. is procurable commercially, and some idea of its



Three-way junction and connections.

resistance can be got from the fact that 0·1 mm. wire, 1 mm. long has a resistance of 0·11 ohm. Bismuth and platinum or bismuth and silver make splendid junctions, and an alloy of bismuth and about 5 per cent. tin gives a thermo-E.M.F. to lead of 44 microvolts per degree. Although such alloys cannot be nicely drawn, they are sometimes cast between smoked-glass

* See Watson's *Physics*.

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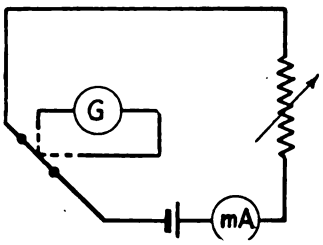
plates. An alternate method is to heat the alloy to well above its melting point and hurl it while molten on to a flat glass plate; the metal runs out into small streams which when cold can be cut off and used instead of the castings mentioned.

A series of silver-constantan junctions is obtained by winding an open spiral of constantan wire and placing it half immersed, lengthwise, in a silver-plating bath. The investigators state that the thickness of the silver should be such that its area of cross section is of the order of 33 per cent. of the constantan core. Two



With separate heating wire.

lines of junctions result, and if one of these is exposed to the heater a remarkably good thermo-pile is formed, the line of demarcation being particularly sharp, but this is not so usual a method for home construction as that outlined below.

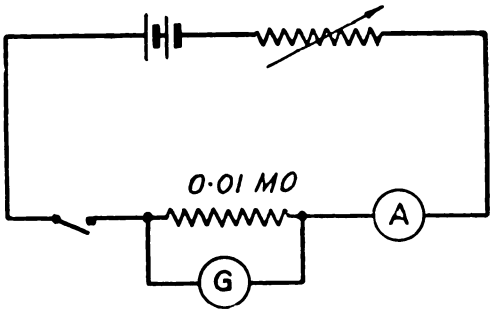
Constructing the Junction.

On an ebonite base affix four or six terminals (according to whether a two or three-way junction is chosen) of the plug-in variety, with screws at the top, to clamp the small pieces of copper to which the junction-wire ends are to be soldered.

Having decided, from published tables or otherwise, what combination of wires to employ, and on the arrangements for leading the current in and out, the copper pieces should be clamped into approximate position before the junction wires are soldered to them. It is now possible to pull taut gently the wires (which should have been previously cleaned by fine emery paper rolled round a match), and with them clamped in this position, the junction itself can be tackled. The smallest conceivable spot of solder and Fluxite is necessary and, if a soldering iron is to be used, it will be found quite sufficient to bring it near to the wires. Wood's alloy, with a melting point at about 66°C., is to be recommended in place of solder, as it requires so much less heat.

If, however, it is decided to make the junction itself before affixing it on the base, it can be kept equally taut by laying weights on both wires, and, if this be done near to the point of contact, it prevents the spread of heat. Despite this advantage, it is usually more satisfactory to construct the junction *in situ*.

Yet another method is to twist gently the wires one over the other, placing them firmly on knife-edge electrodes and fuse together by electrical heating, the current



Circuit for standardising galvanometer.

being gradually brought up from zero until the two junctions separate, or again the twisted wire can be passed through an oxy-hydrogen flame.

When using in conjunction with a galvanometer, this latter must have first been standardised so as to read directly in microvolts, by a circuit similar to that given below and the following readings tabulated :—

(*a*) Milliamperes.
(*b*) Galvo reading.
(*c*) Resistance shunt.
(*d*) Electro-motive-force per centimetre deflection, from which can be calculated the mean value of a deflection.

It will be found that (1) so sensitive is the combined junction and galvo that unless the screening is thorough, a capacity effect is noticeable, and the observer should keep as far away as possible.

(2) A long time must elapse between readings, due to the "creeping" action of the junction.

(3) If accurate reversal readings are required, *i.e.*, with current flowing in the opposite direction, the junction must be permitted to get quite cool.

(4) A serious error will ensue should the three wires (in the three-way type) not cross at the same place. It needs a magnifying glass to make quite certain that they do.

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Resistance in Wireless Circuits. [R144

A lecture to the Radio Society of Great Britain, delivered by Professor C. L. FORTESCUE on February 25 at the Institute of Electrical Engineers.

Introductory.

LET me at the outset express to you my very high appreciation of being asked to give this lecture. It is a great honour to be asked to take part in your proceedings and to come into line with the other distinguished lecturers you have had in the past. Let me also explain to you how it is that I came to choose such an exceedingly dull subject as resistance in wireless circuits. When your secretary's letter reached me, I was struggling with some experiments with a coil which, so far as I was able to calculate, should have had a resistance of about 67 ohms. That coil refused to function altogether, and I eventually found that it had a resistance of over 800 ohms. That coil I had no reason to suppose was as bad as it was. At the same time, I had other examples, of which I will speak in a moment, and I felt, therefore, that there was possibly some ground for a little discussion of the presence of these rather abnormal ohms and the effect of them in wireless circuits.

Resistance is as essential and as unavoidable in wireless circuits as in any other electrical apparatus, and the problem involved is the same, viz.: Firstly, to decide upon an appropriate value for the resistance of each part, and then to maintain it at that value. There is, however, the difference that, whereas in most electrical machinery the permissible rise of temperature places a limit on the resistance, in wireless circuits considerations of efficiency are generally the determining factors, except in large power transmitters where both limitations may be severely felt simultaneously.

The simplest measure of the resistance of a conductor is that given by the familiar Ohm's Law, viz.: the ratio of the steady voltage V to the steady current, I; i.e., $R=\frac{V}{I}$. The power wasted in heat in such a circuit is I^2R, and so an alternative measure is obtained, viz.: the power in watts generated as heat divided by the square of the steady current, i.e., $R=\frac{W}{I^2}$. When dealing with wireless circuits, the first measure is ruled out, because a large share of the applied voltage is usually required to overcome the effects of inductance and capacity. The alternative measure derived from the power generated as heat may, however, be used with certain conventions. As pointed out in subsequent paragraphs of this paper, power is expended as heat in various ways, and it becomes necessary to extend the term "resistance loss" to include the whole heat generated by the presence of the current in the circuit. The effective resistance may then be defined as $R'=\frac{W'}{I^2}$, the current being measured in R.M.S. amperes.

In those circuits where an appreciable amount of power is radiated in the form of electromagnetic waves a further decision has to be made: shall this power expenditure be included when determining the effective resistance of the circuit? It is usual to speak of the effective resistance added to the circuit in this way as the radiation resistance of the circuit and to define it as $R''=\frac{W''}{I^2}$, where W'' denotes the power radiated.

Many instruments, valves, etc., may also have to be considered as forming part of the circuits under consideration, and a still further addition to the resistance may arise from their presence. The power *absorbed* by any such device, divided by the mean square current, again gives the resistance that must be added. If it should happen that the device *supplies power to* the circuit instead of absorbing power from it, then the resistance must be regarded as a negative resistance. In the application of this idea of a negative resistance the power supplied is generally approximately proportional to the square of the current, and the negative resistance is then as much a constant of the circuit as the ordinary positive resistance.

The question immediately suggests itself: What will happen if the negative resistance exceeds the positive resistance? The answer

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is that under these circumstances the power supplied to the circuit for any current I is greater than the power expended. The excess power causes an increase of the current, and this increase will continue indefinitely if the positive and negative resistances are really constant.

An oscillating valve just building up the current is an example of a negative resistance predominating. The current goes on increasing until a steady value is reached, when the output from the valve no longer exceeds the power expenditure owing to the negative resistance of the valve being not truly a constant and having fallen as the amplitude of the current has increased. Any device giving a negative resistance must necessarily have a limitation of this kind unless it is capable of supplying an infinite amount of power.

It follows, therefore, that in the most general case the total effective resistance of a wireless circuit at any instant may be of large or small magnitude, zero or negative, but it cannot be negative permanently.

The Practical Importance of Resistance.

This depends entirely upon the part of the installation. In the high frequency tuned circuits it is necessary to reduce the resistance to low values for the following reasons:—

(A) The selectivity, i.e., the sharpness of the tuning, of a receiving circuit is dependent upon the ratio of the resistance to the inductance. If two continuous waves differing in frequency by one kilocycle induce the same electromotive force in an aerial tuned to one of them, the ratio of the powers absorbed from the two sources of electromotive force is approximately $1+160\frac{L^2}{R^2}$, where L is in millihenries and R is in ohms. Now, at a frequency of one million ($\lambda=300$m) good design gives R/L as about 3 ohms per millihenry for inductances of a size suitable for use in a receiving circuit. This gives a ratio of powers absorbed of about 19 to 1. If the ratio of R/L could be reduced to 0·3 ohms per millihenry, this ratio would become about 180 to 1. When it is remembered that an interfering signal is often much stronger than the signal being received, the desirability of reducing the resistance relative to the inductance becomes obvious. The possibility of doing this by reaction is discussed later.

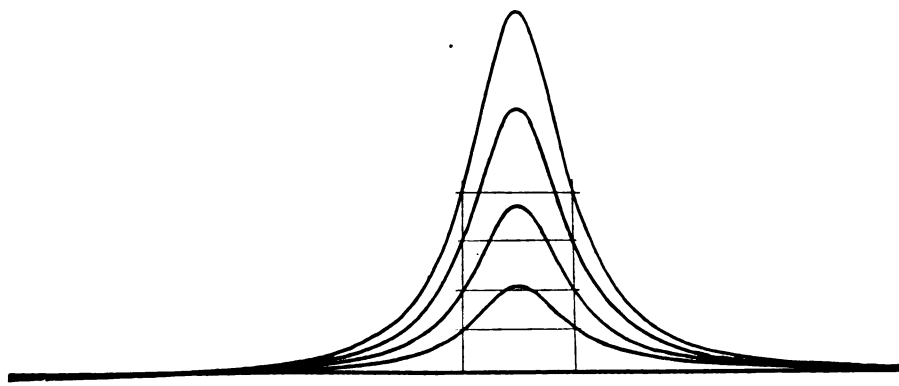

Fig. 1. *Family of resonance curves of varying amplitude but equal damping.*

The above conclusions apply very closely to modulated continuous wave (telephony), but not to spark or atmospheric interference. This interference is a problem to itself, and is only dependent to quite a small degree on the resistance of the circuits.

That aspect, which really is an aspect relating to the resonance curve, is one of the principal troubles of resistance. I am fortunate this evening in being able to show, by a simple piece of apparatus, an actual resonance curve as drawn out, so that you can form some working idea of the shape which such curves do take in practice. The curve is for the single layer coil and condenser on the lecture table. There is under the table an oscillator which is generating a continuous wave, and there is an arrangement of a rotating condenser—

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rotated by means of an arm—which varies the frequency of the oscillator and at the same time causes a spot of light to move from right to left on the board. The horizontal scale, therefore, becomes a scale of change of capacity. Actually, the capacity change is a little under 30 per cent. of the whole capacity in the circuit. The coil has a resistance of a little over 8 ohms at the frequency of the experiment and the condenser is of about 700 picofarads capacity. The voltage is measured by a simple rectifying valve, connected with its grid and filament across the coil so that the rectified current is a measure of the square of the voltage across the coil. Passing the anode current of the rectifying valve through a Weston relay gives a vertical movement of the spot of light; and therefore the two movements combined give a resonance curve. [Prof. Fortescue then drew the resonance curve by tracing the movement of the light spot on the blackboard.]

(*b*) The efficiency of a transmitting aerial and the associated circuits as a radiator of electromagnetic waves depend upon the relative values of the effective resistance, which gives rise to waste of power as heat, and the radiation resistance, which determines the power radiated away usefully. The former must be reduced relatively to the latter if a reasonable efficiency is to be attained. As the frequency increases it becomes more and more difficult to reduce the wasteful resistance. Fortunately, however, the radiation resistance increases as the square of the frequency. This more than compensates for the difficulty of reducing the other resistances, and in practice it is easier to obtain a higher efficiency at the high frequency corresponding to a wave-length of 100 metres than at a wave-length of 10 000 metres. This is, perhaps, one of the advantages of short waves.

Closely related to the efficiency of an aerial as a radiator—if not identical with it—is its efficiency as an absorber of power from an incoming signal. A good receiver is a good radiator, and consequently if the radiation resistance is high and the wasteful resistance low, the aerial will absorb more energy, and incoming signals will be louder than when the conditions are reversed.

In telephone receivers and transformers the resistance is undesirable but relatively unimportant, owing to the fact that the inductive effects usually predominate.

In grid-leaks the resistance must be high and definite—a condition by no means always attained—and, finally, in the insulating materials the resistance should be infinitely high.

The High Frequency Resistance of Inductances.

The losses of power in an inductance may be classified as follows:—

(*a*) Conductor losses;
(*b*) Dielectric losses;
(*c*) Losses in surrounding conductors;
(*d*) Losses at terminals and contacts;
(*e*) "Dead end" losses.

With regard to (*a*), these are greater than they would be under steady current conditions, because the current is unequally distributed over the cross-section of the conductor. This unequal distribution arises from the general principle that high frequency currents always tend to distribute themselves so that no magnetic flux penetrates any conductors. In the case of a straight cylindrical wire the current, by this principle, tends to concentrate on the outer layer. For copper wire of a millimetre or more in diameter, and with wave-lengths not exceeding about 300 metres, the effective resistance is about $\frac{640d}{\sqrt{\lambda}}$ times the steady current resistance, where d is the diameter of the wire in centimetres and λ the wave-length in metres. When coiled into an inductance, it will be more than this owing to the concentration of the current on to the inner surface of each turn.

The exact resistance under these circumstances is very difficult to determine. It is dependent upon the spacing of the turns of the coil and upon the ratio of the length and the depth of the winding to the diameter. With copper wires a rough guide to the best conditions is to choose a diameter of wire given by $d=0{\cdot}6\,\frac{\text{Length of winding}}{\text{Number of turns}}$. This is approximately true for both single and multiple layer coils, and the effective resistance of the coil is then about twice the effective resistance of the same length of wire when straight, i.e., about $1\,300d/\sqrt{\lambda}$ times the steady current resistance. This rule may

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be employed so long as the diameter of the wire in centimetres is greater than $0{\cdot}01\sqrt{\lambda}$.

It is possible to obtain stranded conductors for inductances, i.e., conductors made up of a number of fine wires insulated from one another and arranged in a symmetrical manner in the conductor. If such conductors are used, very careful design is necessary both from the electrical and mechanical point of view. The object is to compel the current to distribute itself uniformly over the whole cross-section. This end can be attained reasonably easily with wave-lengths of from 600 to 10 000 metres; but with wave-lengths below 300 metres the diameter of the individual strands has to be very small, and it is doubtful whether the additional cost is justified except possibly in large transmitting stations if space happens to be limited and first cost is relatively unimportant. An alternative method of securing a more uniform distribution is to employ a conductor in the form of a thin strip wound into a pancake coil. These coils, however, become rather large, and the losses in the inner turns, where the magnetic field is intense, may be surprisingly large, and in transmitting coils damage to the insulating supports has often resulted. It is a remarkable fact that no numerical investigation of the properties of pancake coils has ever been published, at least as far as I am aware.

The question as to whether single or multiple layer coils give the best results naturally arises at this point, but no definite answer covering all working conditions can be given. For wave-lengths exceeding 300 metres multiple layer coils are more compact, and with proper design will have a lower ratio of R/L than single layer coils. Below that wave-length the tendency is in favour of single layer coils, becoming more so as the wave-length is decreased. The multiple layer coil is a little more difficult to make unless special winding machines are available, and particular care has to be taken with the insulation of the individual wires, since it may be called upon to withstand the accumulated voltage of a number of turns of the coil.

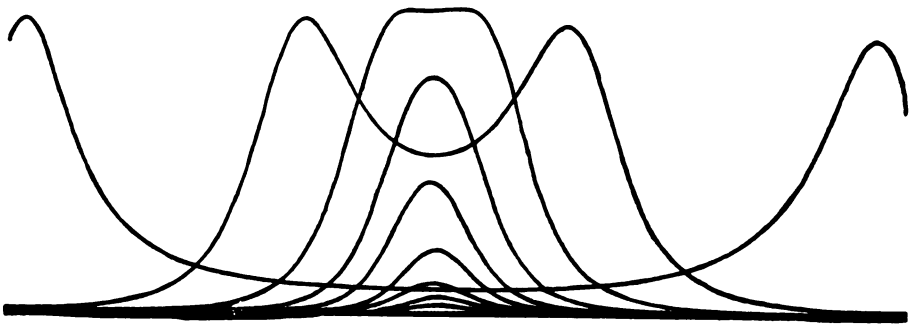

Fig. 2. *Resonance curves of secondary current in coupled circuits with varying coupling. Note that increase of coupling beyond critical value does not increase the received power.*

With regard to the dielectric losses in inductances: these may occur in the insulation of the individual conductors or in the former supporting the coil. The loss in the insulation of the conductors may be avoided by having them air spaced. This, however, is not always practicable, and if it cannot be done, it is necessary either to keep the insulation quite dry or to impregnate it with a non-hygroscopic varnish of good dielectric properties. Good shellac varnish is largely used, but it has the serious disadvantage—with cotton insulation, at any rate—that the solvent always contains water which can never be driven off permanently. In a coil recently tested the dielectric loss between the turns of a single layer amounted to about 0·3 ohm out of a total resistance of about 2·0 ohms. This coil was shellac varnished, baked and then exposed to an atmosphere of 90 per cent. humidity for 30 hours. The resistance was less before varnishing, and with single layer coils which are not actually exposed to water it seems preferable to leave them unvarnished.

The dielectric loss in the former is important in some cases. In a variometer tested by

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the writer recently a ratio of R/L of about 800 ohms per millihenry was found. This enormous loss was apparently due to the fact that the two parts of the outer winding were not directly in series, but were separated by the whole of the winding of the moving coil. Consequently the rather narrow strip of insulating material between the two halves of the outer coil was subjected to the whole voltage of the moving coil, and, being a moulded material—certainly not ebonite—the losses there were sufficient to render the variometer practically useless. When included in the circuit for which it was intended, the resistance and reactance were approximately equal! Troubles of this kind can be avoided by designing the former so that no part is exposed to a strong electric field and, of course, using a good ebonite instead of cheaper and perhaps more easily-moulded material.

The unfortunate owner or purchaser of such coils as this, who had not the means of measuring the resistance, would find, when working under normal conditions, that the reactance and the resistance in his circuits were about equal. I do suggest that in that connection there is a function which this Society could very well undertake, and that is to see that no members of your Society—or, for that matter, members of the public—should have instruments of this kind sold to them. Few amateurs have methods of measuring resistance within a moderate degree of accuracy, and it is very unfair to sell them instruments of this kind when, at a very small increase of cost—in fact, I am not sure any increase of cost need be involved—a reasonable coil could be supplied. Therefore, it does seem to me that it should be possible for the Society to organise some means of testing so that any manufacturer who desires can ask for apparatus to be listed and for the Society to give its approval or disapproval.

With regard to (c), the general fact that there must be losses in any conducting body placed in the field of an inductance is well known; there is, however, curiously little numerical information available. For instance, do the heavy brass terminals often fitted to an inductance add appreciably to the resistance? Does screening make any material difference? How far away from steel-work should coils be placed? And so on.

In this connection the following facts taken from measurements which I have made are of interest. A single layer coil wound on a paxolin cylinder and having an inductance of 11 500 microhenries was used, and the tests were made at a frequency of about 68 000. The resistance of the coil at this frequency was about 28 ohms. Placing a piece of tinned steel sheet 13 in. × 7 in. alongside the coil and about 1 in. from it increased the resistance of the coil by 32 per cent. Surrounding the coil by a piece of galvanised iron netting of 1 in. mesh in the form of a rectangle 15 in. × 24 in. caused an increase of 176 per cent. On the other hand, placing a cylinder of brass 2 in. long and half inch diameter inside the coil half inch from the windings raised the resistance only 2 per cent. A heavy brass terminal outside the coil is thus harmless, but any steel near the coil is to be avoided. In connection with this last conclusion, a case is known to me in which moving the aerial tuning coil in a transmitting circuit up to within a few feet of a steel-framed valve panel led to an expenditure of something like 10 kilowatts in the valve panel itself!

The losses in contacts should be negligible if reasonable care is taken. This is by no means always done, and many switches make bad contact after continued use. This is mainly a mechanical question—the leading principles being freedom for the contact blades to adjust themselves as they become worn, and the absence of unnecessary restraint from the support.

The "dead end" losses occur when only a part of a coil is actually in use. There is a transformer action taking place, in consequence of which there is an electromotive force acting in the coils not in circuit. This leads to dielectric losses between turns, and if the current in the part in use is of very high frequency, there may even be resonance with the natural frequency of the "dead end," with the accompanying heavy conductor and dielectric losses and annoying coupled circuit effects which disturb the tuning. This difficulty is commonly avoided by using a switch which short-circuits all the contacts in turn as the corresponding parts of the inductance are cut out. This is bad design and frequently increases the resistance unnecessarily. There should generally be no short-circuit until at least two-thirds of the inductance is out of use, and then this whole two-thirds should be short-circuited from the free end to the contact, and not from stop to stop.

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The High Frequency Resistance of Condenser.

The losses in this case—at least where reasonable designs are adopted—are entirely dielectric losses. Experiments with dielectrics show that what is termed the power factor is constant over a very wide range of frequencies. If C is the capacity in farads of a condenser made up with a dielectric having a power factor ϕ, the interpretation of this fact is that the product fCR is constant and equal to $\phi/2\pi$, where R' is the equivalent resistance in series with the capacity C, which would give rise to the same losses. For ebonite ϕ is about 0·014, and so, if $f=10^6(\lambda=300\text{m})$,

$$R'=\frac{0{\cdot}014}{2\pi}\cdot\frac{1}{10^6C}=2{\cdot}2\times10^{-9}/C.$$

If, for example, $C=\cdot01$ microfarad, the equivalent resistance would be 0·22 ohm. But at a lower frequency, say 10^3, and for a smaller capacity, say 300 picofarads, the equivalent series resistance would be nearly 700 ohms. This sounds a large figure, but in circuits where such a condenser would be used at this frequency, it would probably not be serious.

It will be noticed that the equivalent series resistance is directly proportional to the power factor. Hence, if this is found for various materials, it is merely a matter of a simple calculation to determine their behaviour in a condenser. Many measurements have been made with different materials—clear ruby mica is the best material known, and ϕ for good specimens appears to be as low as 0·000 3. The impregnated manilla paper used for power cables has a value of ϕ in the neighbourhood of 0·011. Composite insulating materials give values up to 0·1, a figure applicable for paxolin, for example. Values as high as 0·4 have been recorded for paraffined paper.

As far as is known the figure for air is zero. There must, however, be some loss in an air condenser, owing to the fact that the supports for the vanes must be carried on solid insulators. If the whole capacity is C and the capacity of the metallic supports in the dielectric is C_1, then the equivalent series resistance is $R'=\frac{\phi}{2\pi f}\cdot\frac{C'}{C^2}$. For example, when $C=1\,000$ picofarads and C_1 is 3% of this—viz. 30 picofarads, and ebonite is used, for which $\phi=0.014$, the $R'=0{\cdot}017$ ohms (approx.) at a frequency of 10^6.

The power factor might therefore be ten times as bad without introducing any serious resistance to most circuits. In the case of ebonite there is another effect to be considered, and that is the deterioration of the surface when exposed to bright light. The results are very variable, but cases are known in which the resistance between two terminals mounted near one another in ebonite, has fallen from an unmeasurable value to a value considerably less than one megohm after exposure to air and bright light. Thus with a condenser of 1 000 picofarads capacity, if the surface resistance fell to 0·1 megohm, the effective series resistance would be $\frac{1}{4\pi^2f^2C^2Rp}$, where Rp, the resistance in parallel, is 0·25 ohm at a frequency of one million. This is a more important quantity, and if ebonite is used, the design should be so arranged that there are the fewest possible exposed surfaces between the supports for the two sets of vanes. But, even so, 0·25 ohm is not large compared to other resistances in million cycle circuits, and it may be said that for practical wireless work the dielectric loss in air condensers is not serious. The case is different from that of the inductance, because the amount of the dielectric involved is relatively less.

Resistance in Coupled Circuits.

The effects here are in general the same as in the case of single circuits, viz.: a widening out of the resonance curve. It is well known that with tightly-coupled circuits the resonance curve is a double-humped curve giving peak values for the current for two values of the frequency of the incoming signal. This is obviously a disadvantage, owing to the fact that an undesired signal may hit off one hump when the proper signal is being received on the other. As the coupling is reduced, the two resonant humps approach one another without change of amplitude, until a certain critical value of the coupling is reached. If the coupling is through a mutual inductance M, and if R_1^1 and R_2^1 are the resistances of the primary and secondary circuits, the critical value is when $2\pi fM=\sqrt{R_1^1R_2^1}$. No value of M above this will increase the strength of the signal being received: it merely increases the probability of interference being experienced. Reduction of M below this value reduces the signal

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strength, at the same time narrowing the resonance curve. The critical value giving the best signal is thus dependent on the resistances, since it becomes less and less as the resistances are reduced. Any reduction of M, however, brings the humps closer or narrows the resonance curve, and it follows, therefore, that the lower the resistances the better the selectivity. This is true for continuous wave and modulated continuous wave; but in the case of the single circuit it is not true for spark or atmospheric interference.

Reaction; Negative Resistance.

Though officially discountenanced, reaction remains one of the most important problems in connection with receiving circuits. It is necessarily present in every

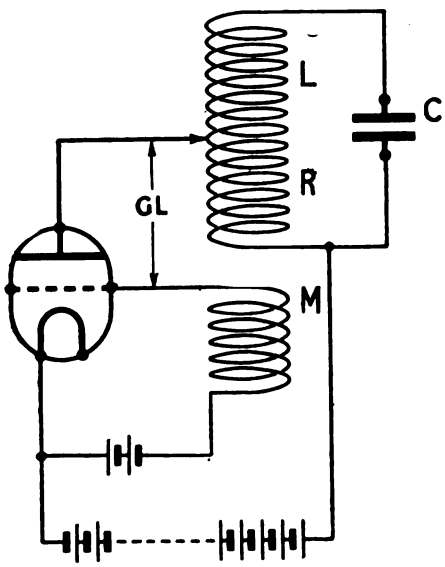

Fig. 3.

form of circuit where valves are employed, and it is now recognised that it is better to provide for it than to leave it uncontrolled and hope that its consequences will not be serious. Reaction arises from any form of coupling—other than through the electron current in the valve—between the circuits connected to the grid and anode respectively. It can be controlled by any form of coupling between the circuits, but the manner of obtaining this control is of great importance. Some arrangements will require the most careful adjusting and will be unstable and apt to break out into oscillations on the least provocation; others will be easy to adjust and stable when adjusted. A very good example of this is the simple grid-oscillating coupled circuit (Fig. 3). Assuming a negative bias to the grid, so that the grid currents are all negligibly small, then when this circuit is connected up it *adds* a resistance to the circuit. This is given approximately by:—

$$\text{Added Resistance} = \frac{b^2L}{R_0C} - bg_m\frac{M}{C},$$

where L and C are the inductance and capacity of the anode circuit respectively, M is the mutual inductance between grid and anode coils, b is the fraction of the whole voltage across the anode coil applied to the anode from the "anode tap," g_m is the mutual conductance and R_0 is the internal resistance of the valve at the anode.

So long as the second term of this expression is less than the first the damping of the anode circuit is actually increased by the presence of the valve. As the mutual inductance is increased, the second term will also increase and eventually equal the first term. At this point the valve is neutral and neither adds to nor subtracts from the resistance of the circuit. Further increase of M makes the expression negative, and the effective resistance of the anode circuit is reduced. This process can only be continued until $bg_m\frac{M}{C}$ exceeds $\frac{b^2L}{R_0C}$ by an amount equal to the resistance of the anode circuit. Beyond this point oscillations set in. For an easy and convenient adjustment, the second stage—i.e., the increase of M from the value at which the resistance is unaffected to that at which oscillations break out—should be comparable with or even equal to the value of M necessary at the beginning of this stage.

If M_1 is the mutual inductance when the valve is neutral, then

$$\frac{bg_mM_1}{C} = \frac{b^2L}{CR_0}$$

If M_1 is the extra mutual inductance necessary to set up oscillations, $\frac{bg_mM_2}{C}$ must equal R_0, the resistance of the anode circuit.

If M_2 is to be, say, equal to M_1, so that the adjustment is not critical, it is necessary

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that $\frac{b^2L}{CR_0}$ should equal R_1.

Typical numbers are: $L=1\,000$ microhenries, $C=500$ picofarads, $R_1=2{\cdot}5$ ohms, $g_m=300\times10^{-6}$ amps per volt and $R_0=30\,000$ ohms. This makes $\frac{L}{R_0C}=65$, and b must therefore be about 0·19. That is to say the anode tapping point should be only about one-fifth of the way up the inductance. With this tapping, the valve is neutral when $M=21$ microhenries (approx.) and oscillations will not set in until it has been increased to about 42 microhenries. There is thus a 100 per cent. variation available for adjustment. If the anode tap is not employed, the value of M which renders the valve neutral is 110 microhenries, and an increase of only 2·5 microhenries (i.e., only a little over 2 per cent.) leads to oscillation.

Such an arrangement is obviously an unmanageable one and should be avoided. The physical interpretation of these results is that the valve resistance must be regarded as being parallel with any circuit connected to the anode. This valve resistance in itself adds to the total effective resistance of a tuned anode circuit an amount $\frac{4\pi^2f^2L^2}{R_0}$ (approx.). If this is large compared to R_1, the total mutual inductance required will also be large, and only a small adjustment will be necessary to deal with the small amount R_1. But by introducing the anode tap, the added resistance of the valve becomes $b^2\frac{4\pi^2f^2L^2}{R_0}$, and it is easy to reduce this to a value equal to R_1 as indicated in the numerical case taken just previously, so making the adjustment far less critical.

This conclusion necessarily applies to any valve circuit having a tuned anode impedance and employing reaction. The lower the resistance of the anode circuit the lower the tapping point should be. Where tuning is used in both grid and anode circuits, a further effect—the coupling due to the electrode capacities in the valve—has an influence on the mutual inductance necessary for oscillations; but the advantages of using the anode tap still remain, since it reduces both the resistance added to the anode circuit and the capacity coupling effect.

The reactive detector, in which there is only an inductance in the anode circuit, is a rather different but yet more important case. As far as considerations of easy control of reaction are concerned, there is no need for any tapping point on the inductance. If grid bias is used, with rectification on the anode slope, the added resistance is approximately $-g_m\frac{M}{C}$ ohms, and so oscillations will set in when this is equal to the resistance of the circuit, i.e., when $M=\frac{R_1C}{g_m}$. Provided that the value of the mutual inductance actually used is only a little in excess of this, the control is not at all critical. It is advisable to obtain the necessary mutual? with the smallest convenient inductance in the anode circuit. That is to say, a few turns closely coupled are generally better than many turns loosely coupled.

Damped Electromotive Forces: Shock Effects.

Atmospheric interference and spark signals are alike in that they consist of intermittent groups of heavily-damped oscillations. If the resonance curve is taken with an electromotive force of this kind, it is found to be much wider than with a continuous wave. The circuit behaves in this respect as though its resistance had been very greatly increased. The value of the added resistance which would open out the resonance curve in this way can be calculated, and when found, can be added to the resistance of the circuit. This introduces an entirely new idea of resistance—a property given to the circuit because the applied electromotive force is a heavily damped one. It is no longer a constant of the circuit varying with every change of the damping and with the initial building up of the source of electromotive force, and it is a debatable question whether it is justifiable to use the term "resistance" for this effect.

What actually happens in the circuit is that the current for any tuning of the circuit is made up of a small component, which is a replica of the applied electromotive force, together with another component consisting of an oscillation having the natural frequency and the natural damping of the circuit. If reaction is used, it causes the natural oscillation to last for very much longer, but the part which is a replica of the

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applied electromotive force is, in general, almost unaffected. The strength of spark signals may therefore be largely increased by using reaction, but there is no appreciable gain in selectivity. This phantom resistance arising from the damping of the incoming waves can scarcely therefore be regarded as being in any way similar to the other effects in the circuits usually denoted by the term.

The Discussion.

Admiral SIR HENRY JACKSON: I think the Society is very much indebted to Professor Fortescue for his extremely interesting lecture, and the very satisfactory experiments and demonstrations he has given us as to the effects of resistance in circuits. Speaking generally, a great many of us do not think half as much about the resistance in our receiving circuits as we ought to do. After this lecture, I think it will come home to us as a very important point in getting selectivity and strength of signal. There is no doubt that everybody knows what resistance is, but I do not think they grasp the very great importance of it in the design of our receiving gear, and the points that Professor Fortescue has brought out are very useful indeed to us, not only in resistance, but the effects of the material in the condenser and other apparatus. Professor Fortescue also referred to a piece of bad apparatus which he had bought, but does not tell us the reason for this very high resistance, whether it was a matter of design or whether it was a matter of the material, perhaps too much varnish, or something of that sort. We should rather like to know the reason, as most of us, of course, use variometers, and we should like to be able to look at our own to see if they have that particular point in them. I think the Society might very well take up the point of trying to help in regard to the material which is bought. It is rather difficult thing for the Society to do—it means treading on other people's toes—but I think the idea is certainly well worthy of consideration. I should like to congratulate Professor Fortescue on his lecture, and to thank him very much for it.

Mr. C. F. PHILLIPS: I should like to add my thanks to those of Sir Henry Jackson for this lecture, because many of us have had the task of plotting resonance curves, but not of having seen them done for us with a little spot of light. Plotting a resonance curve in the usual manner on squared paper is perfectly easy, but it does take a tremendous lot of time, especially if a number of curves are required. Dealing with the question of resistance in radio circuits, Professor Fortescue's trend in this lecture has undoubtedly been to point out the deleterious effects of resistance. From the point of view of the members of this Society, who are interested in experimental work, and from the point of view of the Services, who are interested in highly selective methods of reception, the elimination of unnecessary resistance from radio circuits is extraordinarily important, as Professor Fortescue has shown. But I should like you to think what happens if one has the misfortune, for one's sins, to spend one's life designing circuits for the reception of telephony. It is a totally different problem, and it is extraordinarily difficult to get really good telephony and selectivity in the same instrument. There is no need for me to elaborate, because Professor Fortescue pointed out that, in the case of a coil designed for a 300-metre wave-length, if the resistance per millihenry were of the order of 3 ohms, the amplitude, when 1 000 cycles off the carrier-wave frequency, was 1/19th the amplitude of the carrier-wave frequency. It is generally accepted that, for musical reproduction, it is necessary to have even amplitude for a minimum of 4 or 5 kilocycles each side of the carrier frequency. If one designed one's circuits with these 3-ohm coils, I ask you to imagine what would be the effect on the ear of music so delivered. The amplification of all the higher notes would be extremely small, and the amplification of the low notes would be such that they would be extremely loud. The question crops up in a most marked fashion in the design of those new and fashionable sets, and superheterodyne receivers. We all know what marvellous results they give in the way of amplification, if we try them on short-wave telegraphy, but those who have had the opportunity of trying them on telephony will have discovered that we cannot associate the degree of amplification possible with those circuits with any degree of purity of reception. If you consider for a moment the operation of the supersonic receiver, treating it as comprised of two distinct units—one a tuner-frequency changer and the other an amplifier specially designed to amplify on one frequency. Imagine that that amplifier is so designed that the chosen frequency is 30 kilocycles. Unless, in your transformers—presuming it to be transformer coupled—you provide for it to amplify evenly over a frequency band of 25-35 kilocycles, you must suffer the most extraordinary distortion on the reception of telephony. In order to enable the transformers to amplify evenly for a frequency band of 25-35 kilocycles, it is necessary to introduce into them a large amount of resistance. I point that out because it is not generally appreciated that supersonic receivers do not offer great advantages for broadcast reception, that the mere fact that they are capable of enormous amplification is another way of saying that they are designed to act on almost a single frequency, and the fact that they are so designed precludes their amplifying modulated telephony with any reasonable degree of even amplitude. With regard to the resistance inherent to inductance coils, we found, quite a long time ago, that we dared not use shellac varnish, probably for the reason that Professor Fortescue suggests, namely, the moisture content of the solvent. I should like to ask Professor Fortescue whether he does not think that, for coils designed not to carry power, the use of a really good wax impregnation is not in every way more desirable. Provided that you dry your coils properly first, you do at least coat them with a film which prevents moisture from re-

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penetrating, and the power factor of most of the paraffin waxes is quite low. With regard to the resistance inherent to condensers, I have had the opportunity of measuring quite large numbers of condensers, and I am very glad to see that at last I have one supporter, and a very important supporter, who points out that the leakage resistance, if one may call it so, across insulating material is of very minor importance indeed. Finally, I should like to say how much I appreciate the extraordinarily clear exposition which has been given of things which, although well known to us, we do not appreciate from day to day as we should. It is a proper appreciation of elementary first principles that is so intensely important in design.

Mr. G. G. Blake: I am sure that Professor Fortescue's lecture has given us much food for thought. There is one thing that appealed to me very much (of course, one can obtain the same information, as Mr. Phillips has said, from resonance curves) I refer to the extraordinary increase in sensitivity that one can obtain by the use of reaction, and, therefore, the absolute necessity, if one wants to receive long-range wireless, of the use of reaction. There is one question I should like to ask Professor Fortescue, and that is with regard to ebonite changing under the influence of light. At the present moment I am carrying out experiments with selenium cells, and it would be rather interesting to know if any research work has been done to find which wave-lengths of light are answerable for these resistance changes in ebonite, and whether these changes take place primarily in the ultra-violet part of the spectrum. I should be very glad if Professor Fortescue could give some information on that point.

Mr. S. Ward: I am afraid that I cannot add very much to what has been said, owing to the fact that I have not carried out any very great amount of experimental work with high frequency resistance, but I must say that I appreciate very much the striking way in which Professor Fortescue has brought out the importance of this subject, and the splendid demonstrations he has given. I always feel that, to most people, a demonstration such as we have seen to-night does bring a thing of this nature home much more than it could be brought home by merely talking about it. If you see the actual effect of the various changes which have been made in a circuit, it can be appreciated very much better. The importance of reducing the coupling and increasing selectivity is very great, but, as Mr. Phillips has pointed out, the gain due to that is not always an advantage when you are receiving telephony. I am glad he has raised that point, because he is able to point it out so much better than I am myself, owing to the fact that his research work has brought him into contact with that sort of thing much more closely than has mine.

Mr. J. H. Reeves: The middle one of the curves on the upper figure is of very great interest to me. As Mr. Phillips has pointed out, if we press things to extremes, we really want two sets of coils for any one wave-length. One has to be the coil which is to receive the single wave at the maximum amplitude, and the other the one which has to have the flat top to its resonance curve, and, of course, until amateurs recognise the importance of these two, the manufacturers who have to provide us with an all-round coil are precluded from giving us the ideal in every direction. Therefore, I think Professor Fortescue's remark, in bringing this home to the amateur, will enable us to encourage the manufacturers to produce an ideal coil for telephony and an ideal coil for C.W. reception. May their profits rise correspondingly. With regard to the flat hump in the curve, Professor Fortescue has pointed out that that is due to resistance in the circuit. It is a very funny thing, but some while ago, as you know, I found out that the use of rather finer wire in coils did give that flat hump, or rather, it gave me better definition. The point upon which I ask Professor Fortescue if he can throw light is as follows: Judging solely by improved definition of telephony, for I had no other measuring device available, I got that flat peak, but Professor Fortescue's lower curves show that reaction increases the sharpness of the peak. My experience was that with these fine wire coils the improvement in definition was maintained when reaction was pushed almost to the point of oscillation. I wonder if there is any explanation to that undoubted observation!

Mr. P. R. Coursey: The importance of losses occurring in all parts of any radio apparatus has been very much emphasised by Professor Fortescue

Our photograph shows the company at the recent dinner of the R. S. G. B. Sir Oliver Lodge and Admiral Jackson may be seen in the centre.

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in the curves which he has shown. He has told us how to measure some of those losses, and has also indicated that, as a general rule, the losses in the condenser part of the circuit are reasonably small and could be neglected. That is certainly true, but when one really wants to measure those more or less negligible losses, and one wants to find out something about them, the difficulties of measurement are very much increased. I do not know whether he can suggest any really satisfactory way of doing it, but so far the only real way we have found is the good old thermal method. Unfortunately, that introduces great difficulties when the condenser is a small one intended purely for use in the receiving circuit, and is only practicable when the condenser is of sufficient size to justify its use under large currents and voltages. Then, however, although the thermal method becomes practicable, it is very clumsy. The power factor which Professor Fortescue mentioned for ruby mica is, unfortunately, one which is very liable to variation. Ruby mica, although a more or less definite material, is a very variable one, and power factors varying very widely on either side of the figure he has given, and often very much in excess of it, are only too easy to get. The figure of ·000 3 is a fairly good average, and the lowest I have had any definite measurement of is about ·000 17. The figure of ·000 2 to ·000 25 is one very easily reached under commercial manufacturing conditions, particularly when the condenser is a large one, designed to carry a good many thousand K.V.A. In the smaller sizes, however, the figure is often somewhat larger than that. Of course, the power factor of air is not zero when the currents are large, because, even before the visible corona appears, there seems to be some loss occurring in air. Where the voltage is sufficiently low for no corona to be visible, it is yet possible to measure power factors considerably in excess of ·000 3 and ·002 5, and that is due to the air and not to the insulated supports for the plates. The point has been mentioned about the increase of power factor due to leakage, and it is certainly a good one. It has been emphasised by Mr. Phillips, but in spite of those figures, which are quite true in the general case, it is possible to obtain ebonite which will give resistance losses considerably in excess of ¼ ohm at one million cycles simply due to leakage. A mere touch of a moist hand on its surface is quite sufficient to bring the losses, in some cases, up to very big figures, 20 or 30 times the figures which Professor Fortescue has mentioned. It is apparently some property of the material, and what precisely the nature of the surface is which causes that loss I do not think is very clear. That is merely another of the points which require investigation. The paper has shown us that there are a lot of points which require further investigation if we want to arrive at a real understanding where all the losses are in our radio apparatus. I am sure we all thank Professor Fortescue for bringing the matter so fully to our notice.

Mr. F. L. Hogg: I should like to add my thanks for the most interesting lecture I have heard for a long time. I should like to ask one practical question: Can Professor Fortescue give us any idea of the results of conducting experiments on these lines? On the short-wave receiver now generally in use, it is the usual thing to use an untuned, or rather the miscalled untuned, or fixed tuned aerial circuit and a tuned secondary tightly coupled with reaction on the tuned secondary, the reaction being assumed in each case to be just on the point of oscillation, the fixed tune of the aerial circuit being somewhere above the maximum range of the secondary with full capacity across it. I should be very interested to know what sort of a resonance curve one would get for an input of varying frequency for the resonance settings of the secondary, *i.e.*, how much grid voltage one gets from a certain definite amount arriving at the aerial on any wave-length on each of the settings of the secondary condenser, because when this system of fixed tuning was first proposed it suddenly occurred to me that it is the wrong idea, because when you mistune the loose coupler you would be bound to get a ghastly signal strength. I have since come to the conclusion, however, that one loses an infinitesimal amount of signal strength and also a very large proportion of atmospherics and other interference It is a fairly simple matter to tune in your primary when working on these short wave-lengths. It has been my experience—that in 99 cases out of 100 one gets a little worse condition when tuning the primary than with a fixed tuned primary because the signal static strength is so altered. I should be glad to have Professor Fortescue's opinion as to what the result of such an experiment would be. There is one other point, and that is with regard to taking radiation resistance curves of an aerial. Professor Fortescue has not mentioned this subject, but there is one point I should like to ask him. Suppose you take the radiation resistance of an aerial by the substitution method can he give us any idea of the error in the usual method of neglecting the inductance and increasing the capacity of the condenser to get a dummy circuit in resonance with the drive? What I am anxious to know is the order of the percentage of error by neglecting the inductance. Finally, I should like to ask Professor Fortescue if he can settle a little argument that has gone on in a certain society for a long time past with regard to such curves as he has shown us to-night. He reduced the incoming signal strength for an increased amount of reaction in each case and showed the curves under each other, but there is one school of thought, so to speak, which insists that if one has a certain fixed signal strength and plots these curves, the curve for maximum reaction will be of greater value at every point than any of the others, *i.e.*, that none of the curves will intersect it at the bottom. The other school of thought holds the reverse opinion, that the curves will intersect. I shall be glad if Professor Fortescue could settle that little argument.

The Chairman: I should just like to say a few words on a remark of Professor Fortescue in connection with the shellac varnish question. I think it was suggested that the Radio Society should look after, quite broadly, the quality of components that are sold generally, *i.e.*, that they should set up some means for having units tested and, generally, to improve the apparatus used for wireless reception. I may tell you that the Radio Society has been considering this question for a long time and has actually taken action in the

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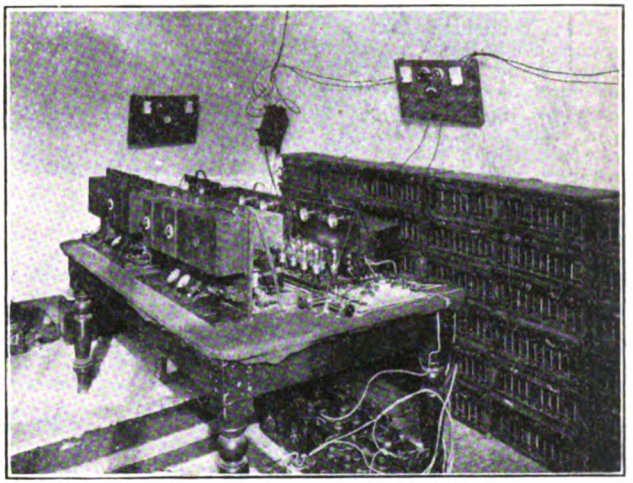
matter. As regards the question of ebonite, it may be news to some of you that the British Engineering Standards Association has now set up a Committee, which has already met once, for the purpose of standardising ebonite for radio purposes, and we hope very shortly that the work of this Committee will bear fruit, and that it will be possible to obtain ebonite that one can be quite certain of. Later on, I hope it will be possible to obtain components of the very best quality and be certain of them. As regards the shellac varnish question, it is interesting, although quite common knowledge, that even the so-called absolute alcohol contains from 3 to 5 per cent. of water which chemists have not been able to dissociate and that there is no such thing as absolute alcohol, because it contains water, but it is beyond me to understand how it is that you find when you have evaporated the alcohol in the varnish, you have not also got rid of the water; that appears to be the case in practice. Speaking again of shellac varnish, this has been replaced, for electrical purposes generally, by oil and other varnishes. The British Electrical Research Association has carried out a large number of researches on various insulating varnishes and probably it has a varnish at hand which will replace shellac and will not have the disadvantage which has been pointed out.

Mr. MAURICE CHILD: My duty to-night is the very pleasurable one of proposing that we give to Professor Fortescue a very hearty vote of thanks for his most interesting lecture which has raised such an interesting discussion.

The vote of thanks was carried with acclamation.

Professor FORTESCUE, replying to the discussion, said: The Chairman has told us that the Society is already considering the proposal which I ventured to put forward for testing apparatus sold to amateurs. With regard to getting rid of water in shellac varnish, the situation is that it can be got rid of, but insulating materials are porous materials, and it comes back again afterwards. Mr. Phillips and Mr. Ward both raised a point with regard to telephony, and the figure of 3 ohms per millihenry and the 19—1 which I quoted represent about the best efficiency that can be obtained. There are many cases in which it is not obtained. I quoted one in which there were 800 ohms per millihenry. It is very general experience that there can be an improvement in what Mr. Reeves called the definition of a wireless telephone by reducing high frequency resistance to compensate for the loss by low frequency amplification which is apt to take place in other parts of the circuit. It is well known that in the transformer magnifier, the 250-cycle notes are not amplified to anything like the extent that the 1 000 and 2 000 cycle notes are. The same thing applies to the superheterodyne. Mr. Phillips has raised the question of wax. I have had some experience of wax and that experience has not been very favourable. It is possible to get a very bad power factor with wax and cotton insulation, apparently if there is any considerable area of cotton and wax in contact. I am not sure what technique Mr. Phillips follows, but my own opinion is that the wax should be a wax of a rather low melting point and that the coil should be dried



The apparatus and power supply installed by the Marconiphone Company at the Ideal Home Exhibition at Olympia for relaying the music of the band to all parts of the show.

out at a temperature at which nearly all the wax will run off, leaving only a trace. Admiral Sir Henry Jackson referred to the variometer I mentioned. I think the loss there was a dielectric loss. It was one of the usual construction in which the circuit consists of one half of the outer coil, then the whole of the inner coil, and then the other half of the outer coil. Consequently, there is the whole voltage of the turns of the inner coil between the turns of the outer coil which are only separated by quite a small distance. I took a pocket knife and could scrape the moulding material away, and my impression is that it is a very inferior black stuff which has no resemblance to ebonite, and I think that was very largely the cause of the loss. I do not think it is a conductor loss at all. Mr. Reeves pointed out that there is no ideal curve and he referred to the coupled circuit resonance curves and suggested that definition might be improved in spite of considerable reaction. I think that is undoubtedly the case. Mr. Coursey made some interesting remarks about ruby mica, and there is no doubt that the power factor of ruby mica is a very variable quantity. Those of us who have had to use very good condensers know the extreme difficulty there is in obtaining really good ruby mica. It is only certain samples which will give a good power factor. I was extremely interested to hear that he has obtained values as low as ·000 17 because that must have been a very difficult measurement to make. He also remarked on the corona losses and the losses in air condensers just before the corona. These, of course, are undoubtedly present but I was not contemplating the use of air condensers in a power circuit at near

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the point at which corona loss sets in. Mr. Coursey asks about measuring the loss in a condenser but he did not mention the somewhat important point as to the frequency. Is it one thousand cycles or one million cycles ?

Mr. COURSEY: At radio-frequency.

Professor FORTESCUE: I think the thermal method is the only way except comparing against the best condensers that one can obtain. If one obtains a number of condensers of different design and different spacing of vanes and with different insulation to prevent surface leakage and so on, and finds that they all agree within a very small amount, then, although it is not a rigid proof it is a reasonable assumption that the losses taking place are not very large. The measurements of the total resistance of circuits do not disagree to any appreciable extent from the calculated values, which shows that there are no large losses in the condensers. The thermal measurement is difficult because the values are very small and the lead-in wires to the chamber may very well give rise to losses which are greater than the losses in the condensers themselves. The leakage that Mr. Coursey mentions would have to be really very bad to introduce such large resistances as he suggests. I am amazed that any cases should have been observable in which the leakage should have been under 100 000 ohms between the plates. I am surprised that it should be so low as that, but when one comes to making measurements of dielectrics one should not be surprised at anything ! The possibilities are unlimited. A speaker raised the question of a tightly coupled aerial on short waves. I think what is happening there is that with a tightly coupled circuit single circuit tuning can be used without loss. The method of determining radiation resistance, spoken of, is entirely a matter of frequency, but on short wave-lengths, where the radiation resistance is a very large proportion of the total resistance in the circuit, the error need not very great. On longer waves, where the radiation resistance is perhaps only less than one-tenth of the total resistance in the circuit, then I think the method of measuring radiation resistance suggested would be a little difficult and would not be so accurate. The same speaker raises the question whether the resonance curves with reaction would intersect with increase of reaction signal strength. No, I think not. The important point is not the question of intersecting ; it is the relative values of the top values and the values at the side.

I should like to say how much I have appreciated the opportunity of giving this lecture and to thank Mr. Terry for the immense amount of trouble he has taken in getting the apparatus ready. I very much regret that one of his co-workers has unfortunately fallen a victim to influenza and is not here to give a hand with these demonstrations to-night.

The American Radio Relay League.

OWING to the fact that Mr. F. H. Schnell has been called to active duty in the U.S. Navy between April and October 1 of this year, Mr. F. E. Handy of Crono has been appointed acting traffic manager of the American Radio Relay League for the time being. Operator of two amateur stations and formerly assistant manager of the New England Division of the League, Mr. Handy has been very successful in other countries.

The traffic department of the League provides the only means by which messages may be sent to any part of U.S. or Canada, free of charge. The League's membership amounts approximately to twenty thousand amateurs, most of whom have transmitting stations. The efficiency of the system has been increased by the appointment of official relay stations, whose owners are bound by promise to forward all messages received.

While Mr. Schnell is with the fleet Mr. Handy will conduct short-wave tests with amateurs, and also keep in touch with the A.R.R.L.'s Headquarters by wireless.

Mr. F. H. Schnell has been asked by the U.S. naval authorities to investigate the possibilities of utilising short-wave apparatus for communication between ships and naval stations.

This investigation through a civilian organisation is regarded as an appreciation of the development by amateurs of short-wave stations.

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The Balkite Battery Charger.

621 : 354 : 3

MESSRS. BURNDEPT LTD. have submitted to us for test one of the "Balkite" Battery Chargers, for which they are agents in this country. Like many useful things, it hails from America, being manufactured by the Fansteel Products Co., Inc., of Chicago. The charger consists of a tantalum electrolytic rectifier with a small step-down transformer to enable it to be operated from the A.C. lighting mains. The whole is contained in a sheet-iron case with carrying handle, occupying a space of about 6½ in. by 6⅛ in. by 10 in.

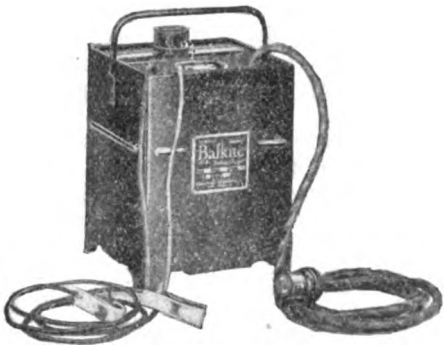
The charger is supplied ready for use; it is only necessary to fill the cell with ordinary accumulator acid (sulphuric acid, Sp. Gr. 1.25), insert the plug-connector in a lighting socket and connect the output wires to the accumulator to be charged, taking care that the red-covered wire goes to the positive terminal and the black one to the negative terminal.

The printed instructions issued with the charger state that two tablespoonfuls of "Nujol" oil should be added to the rectifier cell to cover the acid, which should itself come within half an inch of the top of the cell. The purpose of the oil is presumably to arrest the escape of acid spray, but we have not found oil to be very satisfactory in its behaviour. A good deal of electrolysis takes place in the rectifier during operation, tending to make the oil froth excessively and even to overflow through the vent at the top of the cell. Even paraffin oil was found to froth considerably. It seems advisable, therefore, to use a very thin oil and very little of it, say about two teaspoonfuls or just enough to cover the surface of the acid.

The particular charger we have tested is rated to work off a 210-volt A.C. supply at 50 cycles and to charge a 6-volt accumulator at 2·5 amps. We find, however, that with an input of about 210 volts we scarcely obtain the rated output, and the current delivered to a 6-volt accumulator is only about 2 amps. Nevertheless, the charger does its work effectively and reliably without any noise. Accumulators have been left on charge overnight every night for several weeks, but the rectifier shows no signs of deterioration or change of any kind. It is of course necessary occasionally to add a little water to make up for the loss by electrolysis, as in the case of accumulators; the original acid should keep indefinitely.

As to constancy and efficiency, the Balkite rectifier is without many of the disadvantages of the old aluminium rectifier. For one thing, the sulphuric acid electrolyte has a very low resistance; and such troubles as creeping, crystallisation, precipitation or other deterioration are practically impossible. The potential drop across the rectifier cell appears to be quite low, and is certainly very much lower than is possible with an aluminium rectifier. Another important advantage of the low resistance electrolyte is the reduction of heating up during use. After an overnight run at 2-3 amps it becomes slightly warm. Warming up does not impair the working of a tantalum rectifier, in fact it increases the current output somewhat. The power consumption from the mains is about 50 watts. A special replaceable fuse blowing at 4 amps is included in the D.C. output for safety.

With regard to the constructional details of the charger we have not much information, as everything is in a case which is not meant to be opened. The transformer has a centre-tapped secondary, as both halves of the cycle are rectified. There is only one cell, which we conclude contains a central lead electrode and two tantalum electrodes. Since this cell is made of a black opaque substance and has an opaque top sealed on, we have not been able to satisfy ourselves about the important question of the area of tantalum used; we imagine, however, that this is quite small.



The Balkite Battery Charger.

In view of the simplicity of construction of the charger, the rather low D.C. current output, and the fact that no ammeter is provided, we feel that the price at present asked for the Balkite Battery Charger is rather high. Even the tantalum, which is certainly an expensive metal, is not enough to explain the cost.

With the small reservations indicated above, we consider the Balkite Charger a distinct success. Its ultimate value is of course bound up with the life of the tantalum, but as far as we can ascertain it should last for ever; time alone can decide this question definitely. This charging unit is probably as foolproof and yet effective as anything of its kind which has been put upon the market.

SWEDISH AMATEURS.

It is stated that the amateurs of Sweden are becoming more and more interested in transatlantic work. A cablegram was recently sent by *Radiobladet*, a leading Swedish wireless journal, to the American Radio Relay League, stating that the signals of sixty or more amateur stations in U.S. and Canada had been heard in Sweden by amateurs.

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Radio 6NF. An Amateur Station.

By Alfred D. Gay, F.C.S. [R612

THIS station is situated at 49, Thornlaw Road, West Norwood, London, S.E.27, and is located fairly high above surrounding country. The aerial (Fig. 1) is practically unscreened north, south, east and west, and consists of two wires 85 ft. long, and of an average height of 50 ft.

The earth connection goes to two buried plates beneath the aerial and the main water pipes. On 200 metres a tuned counterpoise is used in conjunction with this system. The counterpoise consists of five wires, 75 ft. long and 10 ft. high, arranged fanwise underneath the aerial. On the 115 to 130 metre band the counterpoise is used alone with about two turns in the A.T.I. The

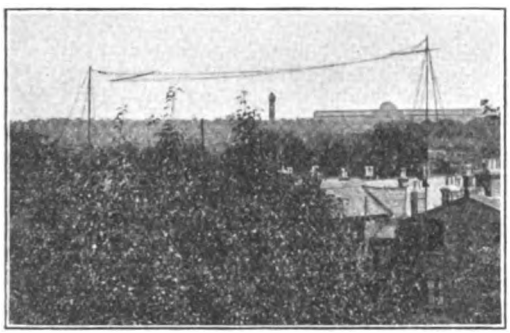

Fig. 1. *6NF's Aerial Equipment.*

inductance in use can easily be picked out in the photograph of the transmitter. It is a rewound, ex-naval loose-coupler: incidentally the original wire on this tuner is being used to wind two large honeycomb coils of 400 and 500 turns each.

The plate and aerial coil are wound with 7/22 copper wire, spaced $\frac{1}{8}$ in. apart, on the 9 in. ebonite former. On 200 metres eight turns are used in the aerial, with a series condenser, and the rest of the coil, which consists of nineteen turns, is used as anode tap. The grid coil is wound with nineteen turns of 20 gauge D.C.C. wire.

The circuit now in use is the 1 DH, and gives by far the best results. (See Fig. 2.) Rectified A.C. is fed to the plate of a Mullard 0/40 at a pressure of 600 volts through a smoothing system, as shown in Fig. 3, four oil-immersed condensers being used across the output of the rectifiers, and six mica condensers of a capacity of one microfarad each across the chokes. The oil-filled condensers may be seen in the photograph (Fig. 4) beneath the larger rectifier unit. With a power of ten watts, the aerial current measures 0·9 amp H.W.

Full wave rectification is used, with eighteen tubes for each half-cycle. Each tube is 6 in. × 1 in. with aluminium electrodes 4 in. × $\frac{1}{2}$ in.; the lead electrodes are slightly larger. Sodium phosphate is giving very good results as an electrolyte, each tube being filled with a nearly-saturated solution leaving sufficient room for one inch of paraffin on the top to prevent creeping. This latter point is most important.

As a centre-tapped transformer was not obtainable, two transformers were used with their secondaries in series. These transformers were not designed for the same primary current, so their primaries had to be put in parallel with a balancing resistance in one of them. This arrangement can be seen on the wall, to the right of the photograph, Fig. 4.

The primary current for H.T., and filament heating for the power valve, are both derived from the same transformer. The main power to this transformer is controlled by a relay, which can be seen between the two

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ammeters on the A.C. control board shown in Fig. 5. This relay is actuated when the aerial switch is pulled over from "receive" to "send." For telephony two receiving valves in parallel are used as controls, the system being the usual grid absorption. The filaments of the control valves are lit by an accumulator, whilst the power valve is lit from A.C., a centre tap winding being used for this purpose, the grid connections going to the centre tap as usual. This gives good results, and DX telephony has been done over 200 miles. The change-over switch can be seen to the left of the photograph with the H.W. ammeter mounted on one edge.

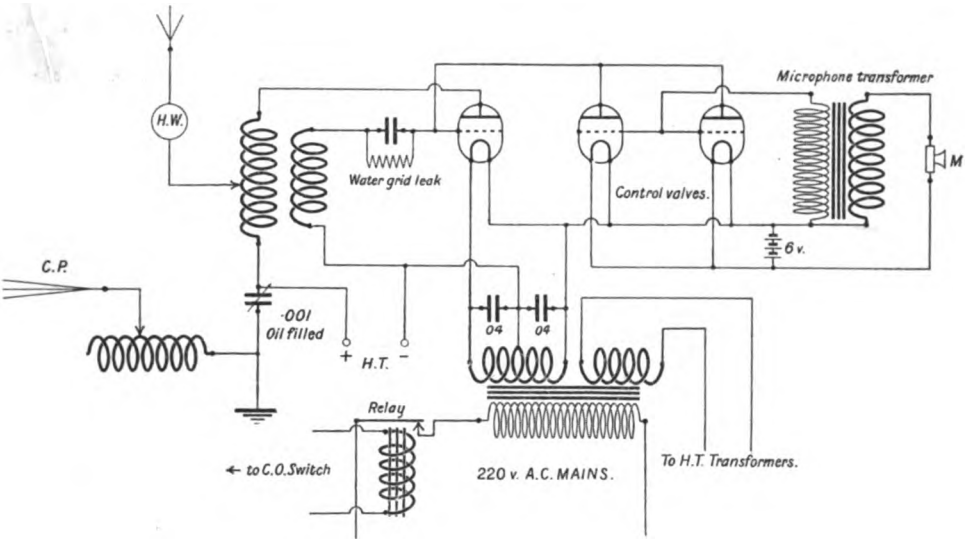

Fig. 2. *The circuit in use.*

On the A.C. control board can be seen two transformers, one for general purposes, which supplies filament heating and various voltages up to 100 volts for the primaries of the H.T. transformers; and a 200—50 volt house-lighting transformer. This transformer is used for accumulator charging, and the chemical rectifiers can be seen in the right-hand bottom corner of the photograph standing in a bath of water. Various electrolytes have been tried, and sodium and ammonium phosphates give the best results. Ammonium phosphate tends to become strongly alkaline after a while, allowing large currents to pass with no rectifying action. If this should occur, acidifying with phosphoric acid will make the rectifier work normally once more. Borax does not seem to give very good results, the solution being rather weak. (The solubility of borax is only 41 grams per litre of water.) Sodium bicarbonate causes bad corrosion of the aluminium electrode, owing no doubt to the ease with which the solution disassociates into sodium carbonate and carbon dioxide. Sodium carbonate has a strong solvent action on aluminium.

In the writer's experience, full-wave rectification is much more economical than half-wave, and the circuit used is shown in Fig. 6. The two ammeters are not essential, but they give an interesting check on the working of the rectifier. Normally the A.C. current should not exceed the charging, or D.C.,

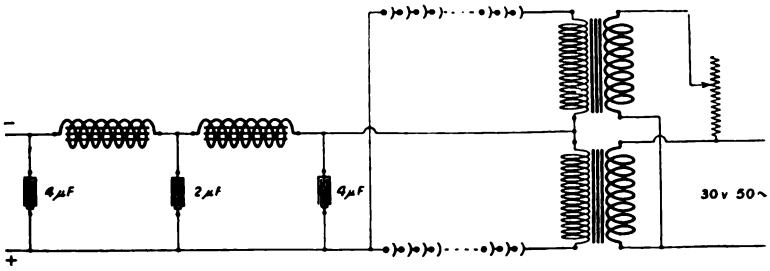

Fig. 3. *The plate circuit.*

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current by more than one amp, which is fair, considering the ill-repute of nodon valves. With four 2 lb. jars, a 10-volt accumulator can be charged at 3-4 amps without heating up the electrolyte. The resistance controlling the charging rate, which is in the primary of the transformer, can be seen in the centre of the photograph (Fig. 5).

Fig. 4. *A corner of the operating room. On the right can be seen the rectifying unit and the oil-filled condensers.*

The receiver at 6NF has been specially designed for efficiency and flexibility. Any number of valves, from 1 to 4, can be used and switches are provided for changing circuits with the minimum of time and labour. Coupled circuits are used, and on short waves only one valve is generally employed. Coils have been made for any wave-length, and can be seen hung above the receiver, which is shown in Fig. 7. The last L.F. valve has a switch to change to either choke or transformer coupling, depending whether the received signals are strong or weak.

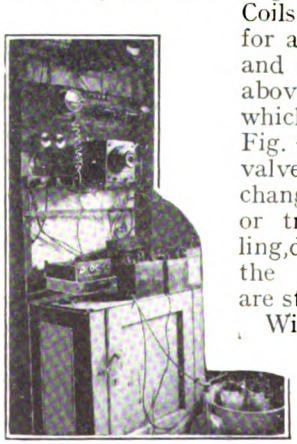

Fig. 5. *The control board.*

Without the slightest doubt, choke amplification gives far better purity, with a very slight loss of power. This fact can better be realised when it is possible to change from one method to another within a fraction of a second. Crystal reception is also provided for, and many interesting results have been obtained on all wave-lengths using coupled circuits. Tuning in 2LO's carrier with a Weston galvanometer in circuit has thrown the needle right off the scale, which means that a current of about one milliamp must be flowing.

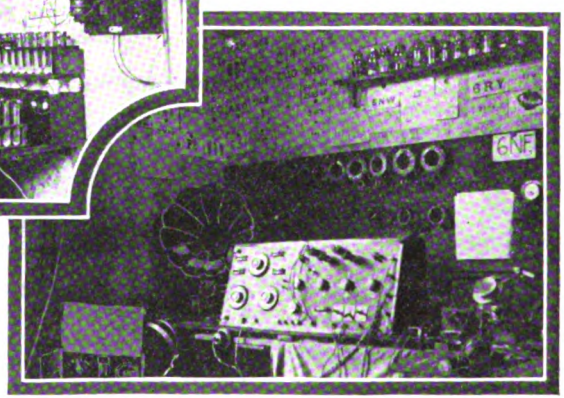

Fig. 7. *The receiver. Note the specially wound coils on the wall and the Flewelling portable receiver on the left.*

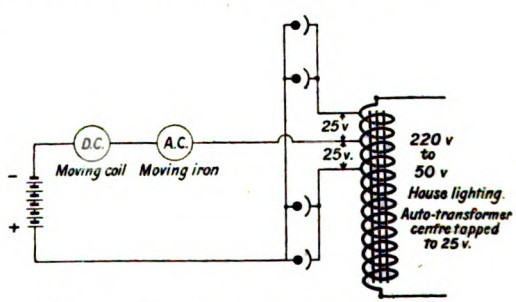

Fig. 6. *The full-wave rectification circuit.*

It might be thought that with all this switching the efficiency of a receiver would be low, but tests made against another tuner resulted in no detected difference. American amateurs have been heard as early as 11 p.m. G.M.T. In the left hand corner of the photograph can be seen a portable Flewelling receiver, which has given some good DX results without an aerial. It contains its own H.T. and L.T. and with a dull-emitter

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valve is entirely self-contained. Stations such as 7EC (Denmark), 0AA (Luxemburg) and 5BA (Newcastle), together with numerous French amateurs, have been heard without the use of an aerial.

So far as transmitting range is concerned 6NF has been reported by three stations in Finland, three in Sweden, once from Gibraltar when using only 4·5 watts, and most other active European countries.

In addition, since this article was written, the station has been operating on 50 watts, and has been heard in eight districts in U.S.A., in India and in other countries.

The "Celestion" Loud Speaker.

[R376·3·009

THE "Celestion" loud-speaker is an interesting instrument of the hornless type, which appears to have one important point of design which differs from anything else on the market. This is that the large diaphragm is entirely free at the edge, being connected to the instrument only at the one central point, where it is fixed to the reed.

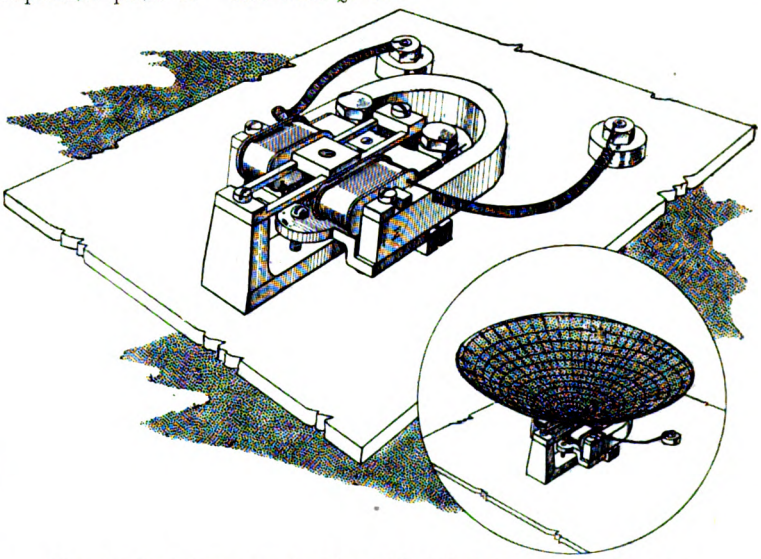
From our sketch the general lay-out of the magnetic system will be seen. The reed is of a curious shape, essentially a rectangle, with the centre part milled out. The diaphragm itself is approximately 9 in. across and is conical. It is made of special paper about ·001 in. thick, stiffened on one side by a spiral, and on the other by radii, of what is we believe to be finely split bamboo, the rods being about ½ millimetre square. After the diaphragm is complete it is treated with a varnish which stretches the paper very tightly.

The whole is enclosed within a mahogany cabinet, the movement being attached to the back, while the diaphragm faces a hole in the front more or less filled in with ornamental tracery (as a protection). In action the loud-speaker is exceedingly good, being, in fact, the best hornless instrument that we have had yet. Its efficiency is practically equal to that of our horn type instrument, while its capacity for dealing with heavy loads is very little inferior.

The tone generally has an excellent quality, although the sample we tried is perceptibly lower in natural pitch than our own standard. It is probable that this would be preferred by many.

Our only criticism is one which is common to every hornless loud-speaker which we have yet tested. There is a certain lack of "roundness" or "fullness" in the rendering of full orchestral music. The point is extremely difficult to define accurately, and would not be noticed by anyone except a very musical person using a first-class set.

The "Celestion" is supplied in various woods and costs £6 10s.



Showing the interior construction of the "Celestion" Loud Speaker. Note the conical diaphragm (inset).

ESPERANTO WIRELESS STATION.

On the completion of the station proposed to be erected for Esperantists on the top of one of the hills of Geneva, nearly the whole population of Europe will be able to listen to exclusively Esperanto programmes. Of the hills in the Geneva district the Salève will probably be selected.

In response to an appeal to the believers in the international language, a sum, approximating very nearly to the amount necessary for the erection of the station, has been forthcoming.

It is probable that the construction of the station will be entirely completed by the early summer of this year. When this is done Germany, Austria, Switzerland, Italy, France and Spain, to say nothing of enthusiastic British amateurs, and the smaller countries, will be enabled to listen to the broadcasting of the important news of the world in Esperanto.

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The Effect of Stray Reactions on the Stability and Amplifying Power of Amplifiers.

By O. F. Brown, M.A., B.Sc. **[R342·6**

An important article reviewing the causes of instability, with some notes on suggested methods of overcoming it.

THE process of adding additional stages of radio-frequency amplification to an amplifier usually breaks down after three or four stages are added

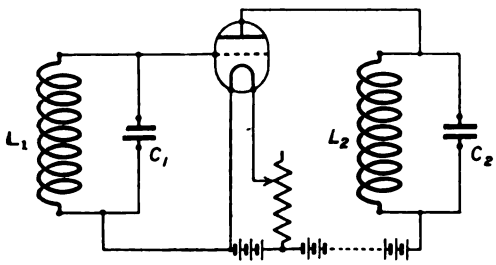

Fig. 1.

through the amplifier becoming unstable and the component valves falling into self-oscillation.

For long waves stable amplifiers can be designed using resistance-capacity coupling or untuned transformers; but instruments of this nature are inefficient for short waves, and it is necessary to employ tuned inter-valve circuits. The results obtained with two stages of tuned circuits are usually superior to those from several stages of amplification by valves coupled by resistances or untuned coils.

The explanation of this instability is to be found in the existence of back coupling between the grid and anode circuits of the valves comprising the amplifier.

These reactive effects can be divided into two main classes: (1) Effects due to unintentional stray couplings, both inductive or capacitive; (2) effects due to the small capacities existing between the electrodes and the internal connections of the valves themselves.

Many of the former class of undesired couplings can be removed by careful design and arrangement of the apparatus, or by electrostatic screening, though this latter method may materially reduce amplification. The latter class of couplings cannot, however, be so removed, since they depend upon the internal design of the valve itself. These small capacities exist between the grid and plate of the valve, and between filament and grid and filament and plate.

Fig. 1 represents diagrammatically the grid and anode circuits of one stage of a radio-frequency amplifier. It is clear that in studying the effect of the undesired capacities the small capacities between the filament and grid and filament and plate can be regarded as included in the capacities of the circuits L_1C_1, L_2C_2, since they are in parallel with the condensers C_1 and C_2, which are usually large compared to the internal capacities of the valve If, however, untuned coils are used in place of the tuned circuits L_1C_1, L_2C_2 it must be remembered that the small inter-electrode capacities and the self-capacities of the coils will

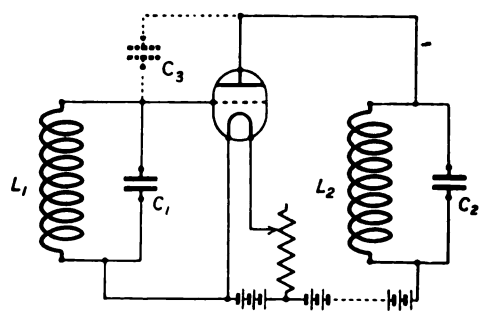

Fig. 2.

form a tuned circuit for some frequency, so that the intervalve couplings cannot be assumed to be untuned for all frequencies.

The chief form in which back coupling takes place between the circuits L_1C_1 and L_2C_2 is thus through the internal plate-grid capacity of the valve, including the connecting leads to the valve holder, which must necessarily be brought close together in connecting the apparatus to the valve.

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This capacity is represented by C_3 in Fig 2. In any complete amplifier the disturbance due to reaction depends on the amplification factor of the instrument and the fraction of the amplified potentials which are fed back by the coupling (either electro-magnetic or capacitive) which is present.

Whether the reactions present in the amplifier produce a damping of the oscillations in the input circuit, or cause the valve to become unstable, depends on the

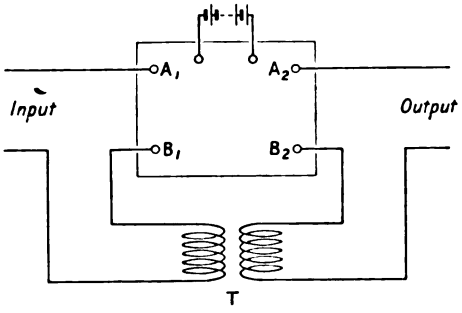

Fig. 3.

phase differences in currents and potentials produced as the disturbances pass through the amplifier.

The general case has been discussed by Professor Gutton* as follows: Let A_1B_1 be the input terminals of a high frequency amplifier, and A_2B_2 the output terminals. Let the current circulating in the input circuit produce between A_1 and B_1 a potential difference whose instantaneous value is given by

$$e_1 = E \sin(\omega t + \phi_1) \quad .. \quad (1)$$

When no coupling is present between the input and output circuits, a difference of potential will be produced between A_2B_2, given by

$$e_1' = KE \sin \omega t \quad .. \quad .. \quad (2)$$

where K represents the amplification factor of the amplifier and the angle ϕ_1 represents the sum of the changes of phase due to the intervalve circuits. K and ϕ_1 depend, of course, not only on the construction of the amplifier but on the nature of the input and output circuits.

If there is any stray coupling between the input and output circuits, either by a leakage of the magnetic flux in the coils of the amplifier or through capacity in the valves, relation (2) will be modified.

* *L'Onde Electrique*, vol. 1, p. 261, 1922.

If I/N represents the fraction of the difference of potential at the output end which is brought back by the coupling to the input end, and ϕ_2 is the sum of the phase changes due to the various couplings in the amplifier, then a disturbance is brought back to the grid of the first valve in the form—

$$e_2 = K/N E \sin(\omega t - \phi_2) \quad .. \quad (3)$$

After amplification this in turn adds a component to the difference of potential

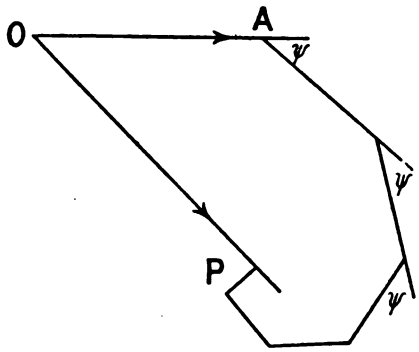

Fig. 4.

at the output end equal to—

$$e_2' = K^2/N E \sin(\omega t + \phi_1 - \phi_2)$$
$$= K^2/N E \sin(\omega t - \psi) \quad .. \quad (4)$$

where ψ represents the sum of the various changes of phase. In the same way a fraction $1/N$ of e_2' will be brought back to the input end of the amplifier, giving another potential component at the output and equal to

$$e_3' = K^3/N^2 \, E \sin(\omega t - 2\psi) \quad .. \quad (5)$$

which in turn gives rise to a new component:

$$e_4' = K^4/N^3 \, E \sin(\omega t - 3\psi) \quad .. \quad (6)$$

and so on. These various components of potential must be added geometrically, the results of such addition depending on the valves of K/N and ψ.

In the case where $K/N < 1$ and ψ is less than $\pi/2$, the vector diagram showing the relations between the sine functions e_2', e_2', e_3', etc., is shown in Fig. 4. It is clear that the vector diagram forms a spiral which tends to a limit in the point P, where the vector OP represents the difference of potential at the output terminals of the amplifier. $O\,P$ is finite and is greater for a given value of N, the smaller the angle ψ. Thus if K/N is near unity and ψ is small, a con-

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siderable increase in amplification is produced by the reactive coupling.

When $K/N<1$ and ψ is greater than $\pi/2$, the vector diagram takes the form shown in Fig. 5. In this case OP is still finite, but the amplification is less than that obtained without reaction.

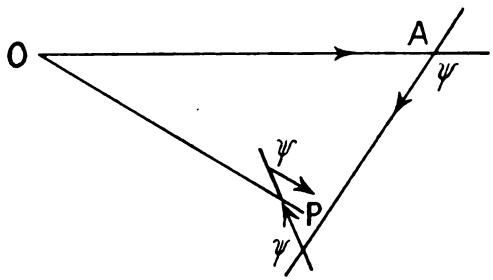

Fig. 5.

It may be pointed out that when the coupling is electromagnetic, it frequently may be possible to pass from the case where ψ is greater than $\pi/2$ to that where it is less by reversing the connections of coils used in the amplifier.

When $K/N>1$ and $\psi<\pi/2$, the geometrical progression composed of the terms e_1', e_2', e_3', etc., becomes divergent and there is no finite resultant (see Fig. 6); the amplification is increased indefinitely and the amplifier becomes unstable in its action.

The resultant increases more quickly the smaller the angle ψ. This angle depends on the frequency of the oscillations and on the coils and condensers in the amplifier. There is therefore one frequency for which it is zero, or a minimum: i.e., a frequency at which the retardations of phase are exactly compensated by advances of phase.

Oscillations therefore tend to be established at this particular frequency, which will be independent of the frequency applied to the input circuit. A very small accidental disturbance may indeed amplify itself and so give rise to oscillations of increasing magnitude.

The value of the coupling $1/N$ which will produce instability is smaller the greater the value of the amplification factor; thus with a powerful amplifier a very small back coupling is sufficient to produce oscillations. For a given value of K, and with $\psi<\pi/2$ it has been seen that an increase of coupling leads first to an increase of amplification (see Fig. 4) and then the production of self-oscillation (see Fig. 6).

In the case when $K/N<1$ and $\psi>\pi/2$, the vectors e_1', e_2', e_3', etc., have no finite resultant (see Fig. 7) and the amplifier is again unstable. It has been seen that a weak coupling when $\psi<\pi/2$ produces a diminution of amplification, and thus, when the coupling is increased, the amplifier may fall into oscillation without a preceding increase of amplification.

The mathematical analysis of the circuits of a multi-valve amplifier (with a view to the investigation of the changes of phase imposed on an oscillation passing through the amplifier) is difficult. The equations obtained are very cumbersome, and it is practically impossible to draw any general conclusions from them.

The most complete attempt at a solution would appear to be that made by Professor Fortescue.* The mathematical analysis of reaction of the output and input circuits of a single valve due to the internal capacities of the valve has been carried out, however, by many other workers including, in particular, Miller.† As may be expected, the results obtained, allowing for slightly different assumptions made in the analysis, are identical.

The input impedance of a valve due to the load in the plate circuits can be shown to consist of a real and an imaginary component representing an effective resistance and an effective capacity. The resistance component may be either positive or negative. In the former case the output circuit throws an additional load on the grid circuit; in the latter case the load on the grid is decreased, so that there is a tendency to oscillation. Whether the effective resistance is negative or positive depends on the nature of the load in the plate circuit. Miller shows that the effective resistance is positive: i.e., that the input circuit absorbs power from the plate circuit and there is no tendency to regeneration:

(1) When the load in the plate circuit is a pure resistance;

(2) When the circuit L_2C_2 is tuned to resonance with the incoming frequency (say ω)—for in this case the plate circuit

* "The Design of Multiple-Stage Amplifiers."—*Jour. of I.E.E.*, 58—65, 1920.

† Bureau of Standards Scientific Paper, No. 351.

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L_2C_2 is equivalent to a large ohmic resistance;

(3) When the frequency of the incoming oscillations is above the natural frequency of the plate circuit L_2C_2. In this case the circuit has a capacitive reactance.

The effective resistance is negative, and there will be a tendency to regeneration when the reactance of the plate circuit is inductive, i.e., when the working frequency is below the natural frequency of the circuit L_2C_2. In this case it can be shown that the tendency to regeneration is decreased when the self-induction of the coil L_2 is decreased, or the condenser C_1 in the grid circuit is increased, or, of course, if the capacity between the grid and plate is decreased.

Analysis thus shows that the phenomenon of reaction between the circuits is indefinite, since all the impedances involved depend in amplitude and phase upon the frequency of the incoming oscillations. The reactance of the tuned circuit L_2C_2 is inductive for frequencies below resonance frequency and capacitive for frequencies above. If self-excitation is not to occur, the condition of resonance for the circuit L_2C_2 must be chosen so low that oscillations which can arise and whose frequencies will be essentially determined by the resonant condition of the grid circuit reactance possess a higher frequency than that to which L_2C_2 is tuned.

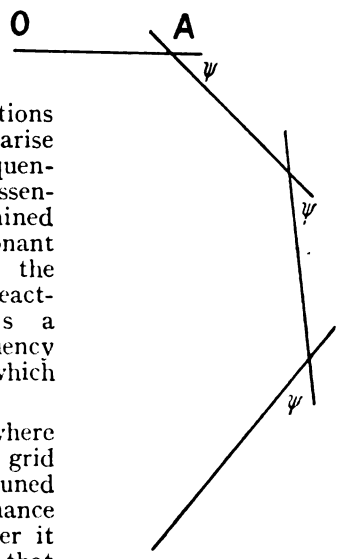

Fig. 6.

In the case where the plate and grid circuits are tuned to exact resonance with each other it would appear that regeneration cannot take place when the circuits are actually in the resonant condition, since each circuit is equivalent to an ohmic resistance. But any attempt at tuning the circuits or any change in the coupling may put the circuits in a very favourable position for causing self-excitation.

It is therefore necessary to consider the experimental methods which have been employed either to cure or to prevent self-excitation in an amplifier possessing tuned grid and anode circuits.

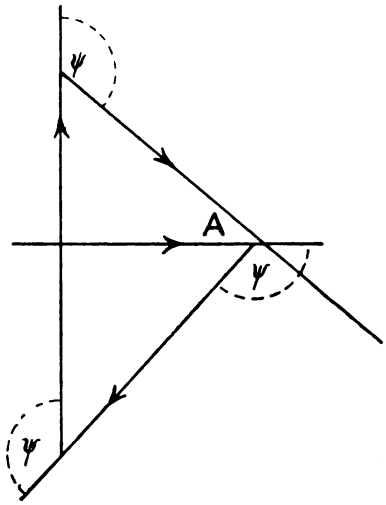

Fig. 7.

One class of methods used are those in which an additional damping in some form or other is introduced into the circuits which are likely to produce self-oscillation. Any method of this nature must involve loss of energy and inefficient amplification, and indeed some methods which have been employed to prevent oscillation aim directly at reducing the amplification, as for example decreasing the filament current or high tension voltage.

Among methods whereby an additional damping is introduced may be mentioned,

(1) Increase of grid potential, which involves increasing grid current and the introduction as it were of a finite resistance across the grid circuit.

(2) The introduction of a resistance into the circuits, or winding the inter-valve transformers with resistance wire.

The underlying difficulty of any attempts of this nature appears to lie in the fact that a valve may, as shown by Gutton, generate oscillations although its amplification factor is small. Such methods as the above only appear to produce inferior circuits as regards selectivity and amplification, without in any way materially reducing the risk of self-excitation.

Another method by which an additional

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damping factor may be applied to the grid circuit is by suitable arrangement of the

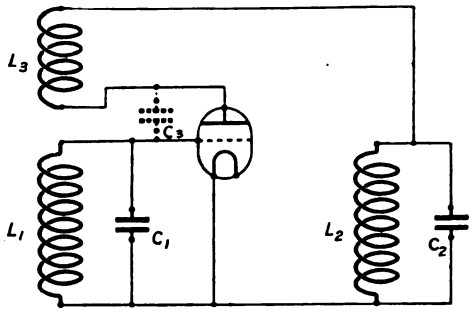

Fig. 8.

aerial circuit. The larger the aerial the less tendency there is towards oscillation. In the case of a tuned grid circuit coupled to the aerial, the tendency to oscillation is less the tighter the coupling, since the aerial circuit absorbs more energy. If the coupling is reduced or the aerial circuit is detuned, there is a greater tendency towards oscillation since the damping by the aerial circuit is decreased.

Another method by which the tendency to oscillation can be materially reduced is by increasing the value of the condenser and correspondingly decreasing the value of the self-induction of the coil in the tuned grid circuit.

As regards the reduction of undesired inductive couplings between the circuits, the following methods have been suggested:—

(1) The enclosure of the coils of the circuits by metal box screens.

(2) Winding the coils as practically closed rings.

(3) Winding the coils on cylinders which are staggered in respect of each other, as suggested by Haseltine in his neutrodyne receiver.

In considering the methods which have been proposed for the prevention of oscillation, it may be stated that very little actual experimental data concerning the results are available. The object of the arrangements used is the balancing of the current through the stray and intervalve grid-plate capacity represented by C_3. Most of the arrangements suggested come from American sources. Usually they are described as applied to two or three valves, and several do not appear practical as far as applied to a complete multi-valve amplifier.

No evidence is available regarding the loss in amplification produced by them, but it is obvious that in many arrangements the loss must be considerable.

The simplest method is that shown in Fig. 8, in which reversed inductive reaction coupling is employed. In this arrangement the attempt is made to compensate for the capacity coupling through C_3 by the inductive coupling by the coil L_3. In this method compensation therefore varies rapidly with the wave-length.

The arrangement of Fig. 9 is one of many variations of the neutrodyne circuit described by Haseltine, in which the compensation is carried out by means of the coil L_c and condenser C_c. The coil is so arranged that the potential across it is opposite in phase to the potential in L_2. In practice the relative phases however in L_c and L_2 depend on the frequency, since it is impossible to make the inductive coupling between the coils sufficiently close to avoid leakage effects and at the same time avoid intercapacity coupling between the coils.

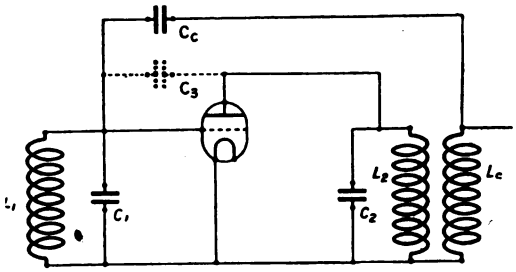

Fig. 9.

Another method of employing neutrodyne coupling is that of Fig. 10, in which the

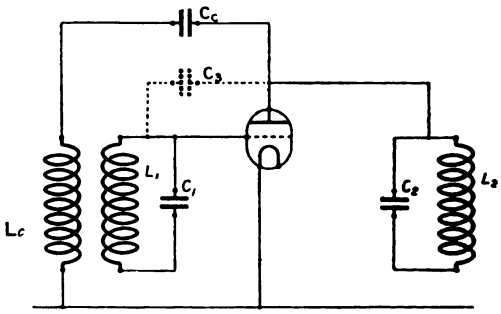

Fig 10.

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compensating coil is coupled closely to the grid circuit. This arrangement has the advantage of allowing any desired inter-valve coupling arrangement to be used in the plate circuit. The adjustment of C_c is critical, and the balance of the reaction effect of C_3 is obtained when

$$\frac{C_c}{C_3}=\frac{L_1}{M}=\sqrt{\frac{L_1}{L_c}}=\frac{N_1}{N_c} \quad .. \quad (7)$$

where M is the mutual induction between L_1 and L_c which is assumed to equal $\sqrt{L_1L_c}$, and N_1 and N_c are the numbers of turns respectively in coils L_1 and L_c. It has been stated that with this arrangement a balancing effect can be obtained over a wide range of wave-lengths on the same adjustment.

In applying the neutrodyne arrangement to actual amplifiers, Professor Haseltine makes the balancing coil part of a specially

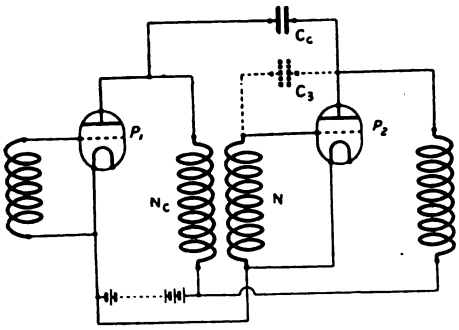

Fig. 11.

wound high frequency transformer as shown in Fig. 11. In an instrument he describes, these special transformers had 13 turns of No. 22 D.S.C. wire as primary winding wound on cylinders 2¾ in. in diameter, and a secondary winding of 55 turns of the same wire wound on cylinders 3 in. in diameter. The neutralising condensers had a maximum

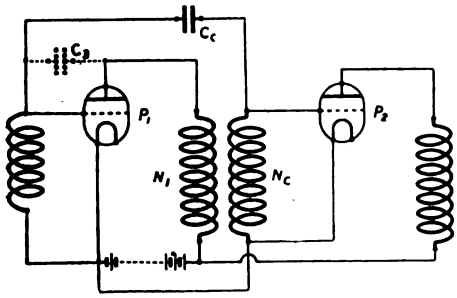

Fig. 12.

capacity of 1·5$\mu\mu$F. Professor Haseltine claims a radio-frequency amplification of about 11 per stage.

In Fig. 11 the disturbance it is desired to neutralise is assumed to be at P_2 in the plate

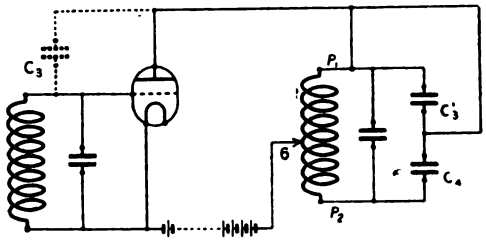

Fig 13.

circuit of the second valve, and the compensating condenser C_c is connected between the plates of the valves. In Fig. 12 it is assumed that the point at which the disturbance is to be neutralised is P_1. In

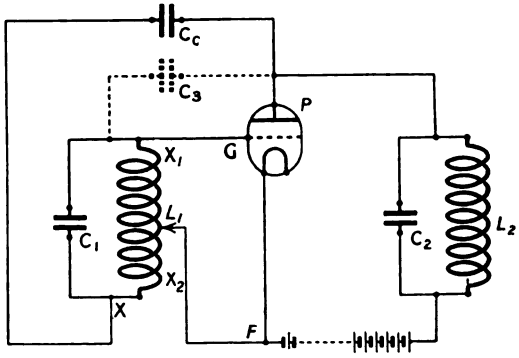

Fig. 14*a*.

this case the transformer formed by the coils N_1N_c has a step-down action, and the compensating condenser C_c is connected between the grids of the valves.

Another variation of the neutrodyne method consists in connecting the high tension battery to an intermediate point on the plate coil L_2, as shown in Fig. 13. In this arrangement the potential of the end P_2 of the coil L_2 will be opposite to that of the end P_1. The portion SP_2 then becomes the balancing coil. The reaction effects are balanced by the condenser C_4. In order to make the necessary balancing capacity larger and of more convenient size, the introduction of a further condenser C'_3 to increase the interelectrode capacity C_3 has been suggested. The circuit L_2C_2 is

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coupled to the grid of the next stage either by coupling a coil to L_2 or by connecting P_1 to the next grid through a condenser. In this latter case S is moved nearer to P_2, so as to increase the potential that can be applied to the next grid.

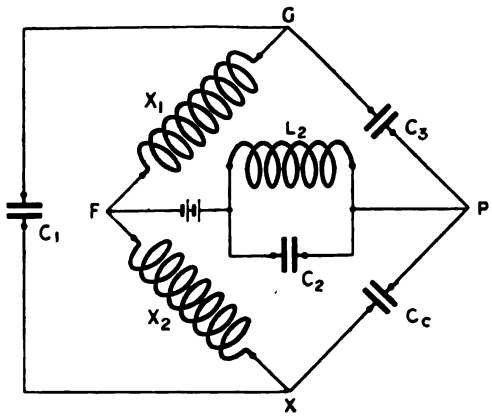

Fig. 14*b*.

Another general class of methods for preventing regeneration may be described as Wheatstone Bridge methods, in which the input and output circuits are isolated as far as reaction is concerned by being made portions of the diagonals of the bridge. This principle is employed in the Rice circuit which is very popular in America. In this arrangement the coil of the grid circuit is divided by the connection to the filament. The compensating condenser is connected to the lower end of the input circuit and to the plate of the valve. The arrangement is shown in Fig. 14*a* and the equivalent bridge diagram in Fig. 14*b*.

When a balance is made between $C_cC_3X_1X_2$ the reactive currents through C_3 are compensated by the currents through C_c. Thus the grid condenser C_1 is isolated from reaction by the circuit L_2C_2, provided other stray capacity coupling is avoided.

It has been claimed that stable amplifiers with four or five stages of radio-frequency amplification have been constructed in this way.

Another bridge arrangement is shown in Fig. 15. In this arrangement the arms of the bridge are all capacitive. The coil L is a high frequency choke, but such that its distributed capacity provides a by-pass for radio-frequency currents. The capacity C_4

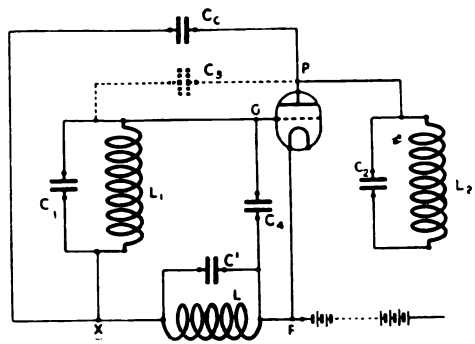

Fig 15*a*.

may be either a small condenser or the internal capacity between the grid and filament of the valve. The extra circuit elements are thus only the compensating condenser C_c and the coil L.

Many other arrangements for compensating for regenerative effects have been suggested, but (as already stated) no reliable data are available concerning their effects, and it will also be seen that no very definite information is available which would tend to show whether the tendency to self-oscillation is due mainly to the internal design of the valve or valve holder or to the arrangement of the circuits in the amplifier.

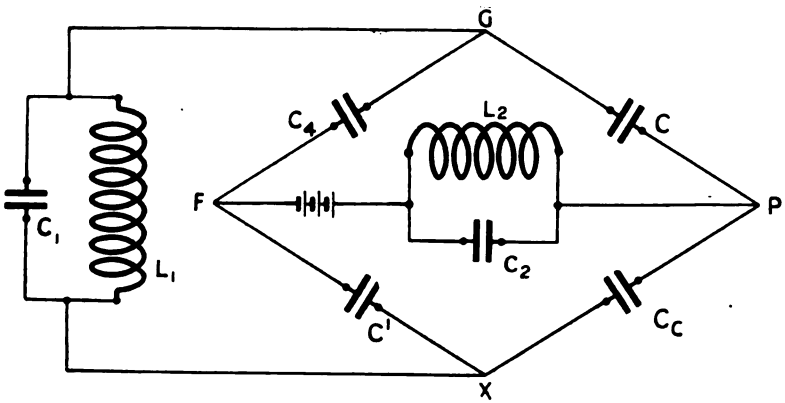

Fig. 15*b*.

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Long-Distance Work.

By Hugh N. Ryan (5BV). **[R 545·009·2**

IN this article I have two months' work to report, instead of the usual one month's. It happens, however, that most of the interesting long-distance work during the period covered by this article was performed during the first of the two months, owing to the considerable deterioration of weather conditions (from a DX point of view) which set in about the end of February.

I will therefore divide this article into two parts, dealing respectively with the two months concerned. This will help to preserve the general continuity of the series.

The first half, then, is the report which would normally have appeared last month, and covers the period from the middle of January to the middle of February.

JANUARY—FEBRUARY.

The country which, I suppose, occupied most of our interests during the latter half of January and the first half of February, was South America in general, and Brazil in particular. A number of our stations figured prominently in the opening up of communication with various countries in South America, but the laurels for the most interesting work—that with Brazil—go to 2NM.

A number of us had been hearing the call sign WJS for some time, without knowing who it was, and some of us had called him without receiving any reply. 2NM, however, succeeded in connecting with him, and found that the signals came from a small portable transmitter accompanying the Hamilton-Rice expedition in the wilds of Brazil. Of all the famous amateur achievements, this Brazilian contact, and last year's work with WNP, must rank as those of the most actual practical use, in that in each case an expedition, cut off from all other means of communication with the outer world, was kept in touch by amateur radio. Good business, N Emma!

As for the other South Americans, signals from Argentina, Chile and Mexico are now heard nightly in this country, and although regular communication with these countries has yet to come, 2OD is leading the way in this direction.

There is little to be said about the United States, as our best stations are now in touch with all the Eastern half of the States as easily and regularly as they are with the mainland of Europe.

The stations I mentioned last month, as being in touch with large numbers of Americans, are still working at the same rate; and in this connection I must apologise for the omission from last month's list of two of our leading stations, 2JF and 2SZ. The number of Americans worked by each runs nearly into three figures.

Although the work with America has been so satisfactory, the same cannot, I think, be said of the work with Canada. One would have expected to find that Canadians would be even more keen to work us than Americans; very likely this is so, but the results are somewhat disappointing. From such detailed lists as have been sent to me, it would appear that on an average our stations work about five Canadians for every 100 Americans. This discrepancy seems too great to be accounted for by the greater number of stations working in America. Nearly every Canadian we work is in Nova Scotia, and most of these in Halifax.

It is to be hoped that our men will try, with the help of the Canadian coast amateurs, to reach further into Canada.

The only important developments on the Continent are the contacts of Spanish EAR2 and EAR6 with America, and of Mosul GHH (a British-operated station) with Australia.

As I dealt at such length with London stations last month, I will be very brief about them now. All the well-known Londoners are steadily working America, while 2OD, 2NM, 2SZ and 2KF occasionally work the Antipodes.

2KF recently told me that he had practically given up DX in favour of another line of experiment, but as I heard him working Australia a few hours later I am not convinced.

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Those who often hear 2NM (and who does not ?) will be interested to hear that a meeting of London transmitters recently presented him with an aerial ammeter, about a foot in diameter, and reading to 18 amperes.

6LJ still holds (and probably always will hold) the record for the number of Americans heard, but 6TM has taken from him the record for the number heard at one sitting, having heard 150 Americans in five hours.

5NN has also done very well in American reception, in addition to a great deal of two-way work. 2WJ has worked 70 Americans and an Australian, and has been heard in India. 6NH is added to the list of Londoners in touch with America. 6NF has, I think, the best log, having worked 127 Americans and seven Canadians. 6DW, who has not been transmitting for some time, has just started in again, and is doing some good work in reception. 6UV has been working quite a number of Americans, and has been heard in the States when using only seven watts on a receiving valve.

In the Isle of Wight 5TZ is putting strong signals into all parts of Europe, but has had no luck, so far, with America. 2IL of Southampton is working chiefly on telephony, which is heard at very good distances, and has been reported in Finland.

In the Eastern Counties, 5QV and 2LZ are keeping the work going. 2TO is in London at present, and therefore not working.

5QV is working a number of Americans to schedule, and has had a very interesting test with Czecho-Slovakian OK1, whom he worked after sunrise in England, the sun also being well up in Praha, where OK1 is located. (By the way, I gave his location as Plzen last month, but he appears to have two QRA's, and I think he transmits from Praha.)

2LZ has worked a number of Americans. The call-sign 2MI, once familiar in London, has been re-allotted in Margate, and may be heard well in south-east England. He uses quite low power, as yet.

In the West the once famous and very active "gang" appears to have dwindled to one solitary station, 6RY. The loss of 5KO appears to have made a bad mess of DX in that part of the country. However, the one survivor mentioned is going as strong as ever, and is working America quite in last year's Western style. He has reached as far as California, and has been heard in Argentina.

In the North I think the most interesting report is that of the confirmed reception of Japanese JFWA, Tokio, by 2AUI of Birkdale. We have been reading about this Japanese station, owned by Mr. Hiroshi Ando, in American papers for a long time, and are very glad that he has been heard over here. The reception was on the usual "detector and one-step" and an indoor aerial.

2JF is probably the "biggest noise" in the North, and has worked a very large number of Americans and an Australian. He has been received in the 7th American district (a rare accomplishment amongst British amateurs), curiously enough by 7JF.

2CC has now his new generator working, and is putting signals regularly into America. 5MO has worked Algiers, being the first British station to do so. He has also heard HVA, in Indo-China (this is, by the way, the station which heard 2KF last month).

In Scotland, 2TF has done most of the work this month, having worked a number of Americans, and exchanged calls with Australian 3BD. 2TF and 2OA both received A3BQ on February 9 (when he was also, by the way, quite strong in London).

Just too late for inclusion in last month's notes I heard of two more active Scottish stations, 5JK and 2VX, both of Aberdeen, who are, with the exception of 2JZ, the most Northerly British transmitters. Both are doing good DX work on 10 watts.

FEBRUARY—MARCH.

Before proceeding with the main part of this half of the report, I must devote a few lines to an achievement which actually belongs in the first half, but which I have put in here in order to report it in the light of later knowledge. I refer to the excellent work of 2OD in establishing telephonic communication with Australia and New Zealand. His first success in this direction was achieved early in February, at a time when we were just beginning to hear the New Zealanders again. It will be remembered that when they were heard last year, they appeared suddenly, lasted a few weeks and then faded away again. Many of us expected them, for purely seasonal reasons, to appear again for a similar period some time in February or thereabouts.

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When they duly did so, therefore, there was much rejoicing among the "prophets," and we were all interested to see whether they would stay for a time similar to that of their early winter appearance. Unfortunately, as we know now, they did not. Whereas previously they appeared with almost clockwork regularity every morning, their appearances this time were extremely spasmodic. On one or two mornings their signals were of very great strength; but these mornings were rare.

At the time of writing (the middle of March) they still come through very occasionally. The Australians, on the other hand, never completely disappeared for long. Their signals did, however, improve very considerably about the same time as the reappearance of the New Zealanders (though the Australians were, of course, heard almost entirely in the evenings and the New Zealanders in the mornings).

It was during this "good period" that 2OD worked Australian 3BQ on telephony and was heard in New Zealand, also on telephony. He repeated this achievement early in March, when conditions were not by any means so favourable.

This augurs well for the success of long distance telephony next winter, when it appears probable that all parts of the world will be linked by amateur telephony. But it will be a very long time indeed, I think, before the phone entirely displaces the key. I, for one, shall be sorry when it does, but there is certainly a great deal of very interesting phone work in store for us.

Another important achievement is the communication between this country and Japan, which was actually accomplished in January, but which has only just been confirmed. The honours this time go to the North, and are shared by 5DN (Sheffield) and 5MO (Newcastle). The Japanese station was JKWZ.

Apart from the important records already mentioned, steady work has been carried on by other stations, and I will briefly report the outstanding features of this.

In London 6NF again provides the "star turn." He has worked about 160 Americans, and has been heard in Cachar (near Calcutta) and on the Pacific Coast of America. 2DX now has both a 22-metre transmitter and a 22-metre licence, which would appear to be a somewhat rare combination. He tests at 12 noon and 12 midnight, and would be glad of reports.

2YQ has come to life again, and is working a number of Americans. 5GF, who has been trying for some months to acquaint the Americans with his presence "on the air," has now succeeded, having reached the 3rd and 8th U.S. districts on very low power. 5ZN, who is handicapped for transmission by lack of power supply, is making good use of his receiver, having heard a large number of distant stations, including "A's and "Z's."

About the middle of February my own new 95-metre transmitter was at last made to work properly, after the series of mishaps I mentioned in the last report. It apparently decided to behave, as the first night's work brought forth some thirty reports from America. On that and a few subsequent nights about twenty Americans were worked, several before 11 p.m., so 5BV can at last be said to be "on the air" again, after several months' absence.

Mr. Somerset Murray, of Cambridge, has been conducting some interesting experiments on 20 metres, on which wave he has heard American 1XAM (Mr. Reinartz), at about 4 p.m., on a hastily-made single-valve set.

5DN, of Sheffield, has now received the reports of his low-power tests with U.S.A. which I mentioned some time ago. Their success is indicated by the fact that his signals (of less than 20 watts) reached as far as Kentucky.

5BA (Newcastle) is another of the old hands who has returned to the game after about a year's absence. He is working America regularly, as are 2CC and 6FG, also of Newcastle.

6KK of Blackpool has started DX fairly recently, and is at present only using 15 watts. With this he has worked most of Europe, and on several occasions has worked America.

In Worksop, two receiving amateurs, Messrs. Martin and Davidson, are doing good work, and doubtless looking forward to joining the transmitting ranks. Both receive Australia and New Zealand.

It will be interesting to note how far into the Spring we can keep the work going. Will all those engaged in DX please report to me by April 10th for next month's article.

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For the Esperantists.

Extracts from E.W. & W.E., March, 1925.

Resumoj el Artikoloj en E.W. & W.E.

Marto, 1925. [399(R800)

LA REKTIFA DETEKTORO.

F. M. Colebrook, B.Sc., A.C.G.I.

[R49

La unua parto de artikolo pritraktanta la problemon de kristala rektifado. La aŭtoro de la artikolo komence montras ekzemplojn de "statikaj karakterizoj" de la galena kaj perikona kristaloj, kiujn la artikolo traktas.

Poste li diskutas tion, kion li nomas la "rektifa karakterizo" aŭ "dinama karakterizo."

Grava punkto trovita estas ke, kiam ajn ekzistas altrezistanca ŝarĝo laŭserie kun la kristalo, la trapaso de la kontinukurenta elemeta fluo tra ĉi tiu ŝarĝo naskas K.K. tension, kiu transiras la kristalon mem. Bedaŭrinde la tensio ĉiam iras laŭ tia direkto, ke ĝi malhelpas la rektifadon, kio montras, ke potenciometro helpos al ia ajn kristalo, kvankam ĝi estos necesa nur ĉe kelkaj.

La konduto de la kristalo rilate al sia elmeto estas ankaŭ pritraktita inĝenie, kaj oni ricevas la finan rezulton, ke la kristalo dum funkciado devus agi kiel generatoro posedanta difinitan internan rezistancon.

La aŭtoro poste pritraktas la temon de efikeco, speciale rilate al la plej bona rezistanco de la ŝarĝo. Dum kalkulado de l'efikeco, fariĝis necese ellabori la altfrekvencan rezistancon de l'kristalo.

La artikolo ankaŭ diskutas la utiligon de la kristalo kiel "potenciala" rektifikatoro, t.e., utiligo rekte en la krada cirkuito de l'valvo, kaj montras, ke ĝi povas esti tre efika.

Oni eksperimentis kun diversaj metaloj kiel kontaktfadenoj, kaj el la rezulto oni konkludis, ke ne estas grava diferenco. Variigita kontakt-premado ankaŭ faris malmultan diferencon en la efikeco, kvankam ĝi kaŭzis grandajn ŝanĝojn en la detektora rezistanco, kiu bezonas ŝanĝojn je la cirkuitaj konstantoj por konservi la saman efikecon.

La matematika analizo disvolvita por la ĉi-supra esploro estas ankaŭ uzata por esplori heterodinan kaj supersonan ricevadon. La granda sentiveco de bata ricevado estas klarigita, kaj (grava punkto) oni montras ke, je taŭgaj cirkonstancoj, la frekvenca ŝanĝo ĉe la supersona detektado, kiel ĉe la kristala, estas sendistorda.

PRINCIPOJ KAJ METODOJ RICEVI PROVIZON DE ALTA TENSIO PER KONTINU-KURENTAJ ĈEFTUBOJ PUBLIKAJ.

L. C. Grant (2QP).

[R355

Priskribo de ĝeneralaj principoj sekvotaj por utiligi ĉeftubojn de kontinua kurento kiel fonton de provizo por funkciigi valvoscilatorojn. La artikolo montras, kiel oni povas malmultakoste funkciigi malfortan sendilon pere de la publika elektra provizo en okazoj kiam la valvoj bezonas platan tension de ne pli ol 500-600 voltoj.

La ordinara aranĝo de publika provizo estas per 3 fadenoj, kun la neŭtra aŭ meza fadeno konektita al tero. Tiurimede, la potenciala diferenco inter la pozitiva aŭ negativa konduktoro kaj tero estas 250 voltoj. Ekzistas tamen la risko de akcidenta mallonga cirkuito pro alterigo de unu el la "eksteraj" konduktoroj—positiva aŭ negativa—kontraŭ kia risko oni devas kompreneble sin gardi. La artikolo montras, kiel atenti tiun aferon, por ke ne estu troa danĝero.

Por lumigado, unu-flanka provizo estas preskaŭ ĉie uzata. Kiam la pozitiva flanko estas uzebla, iu lampo aŭ rezistanco de minimume 200 omoj estu konektita serie kun la pozitiva fadeno; tio evitas la eblecon de mallonga cirkuito ĉe la sendila flanko de la provizo. Karbona lampo de 32-kandelpovo aŭ metal-filamenta lampo taŭgas.

Kiam oni uzas la negativan flankon, la neŭtra aŭ alterigita konduktoro fariĝas

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pozitiva, kaj se ĝi estus konektita senpere al la valva anodo, ĝi alterigus la anodon. Kondensatoro de .05-.5m.f. devus esti konektita serie kun la tera konektajo, kaj tiumaniere evitus metalan kontakton kun la tero.

Utiligante la du eksterajn flankojn, t.e., la pozitiva kaj negativa de la ĉeftubo, kiu liveros ĉirkaŭ 500 voltojn por anoda uzo, oni povas funkciigi 30-vatajn valvojn.

IZOLATOROJ POR ALTA FREKVENCO.

Multaj izolatoroj, kvankam bonegaj por ordinara uzado ne estas kontentigaj ĉe altfrekvencaj cirkuitoj pro la grandaj dielektrikaj perdoj.

Tiu artikolo enhavas rezultojn ricevitaj je radio-frekvenco de S-ro.R.V.Guthrie, de la Ŝtata Universitato de Iowa, kaj de Sroj. Preston kaj Hall, de la *Bureau of Standards*. Oni montras la rezultojn per faktoroj de potenco. Traktante eboniton kiel la unuon, oni povas trovi la proporciajn perdojn de aliaj materialoj, multobligante tiujn per 100.

La tabelo de rezultoj montras, ke Parafino, kun ·00016, havas la plej malgrandan dielektrikan perdon, dum la perdo de ardezo estas tiom granda, ke ĝi tute ne taŭgas por radio-instrumentoj.

ERAROJ EN MEZUROJ.

P. K. TURNER.

[R800—R519

Tre simpla klarigo kiel trovi la taksitan ĝustecon kaj plej probable veran valoron de mezurita kvanto. La aŭtoro komencas per konstato, ke nenia mezuro estas iam precize ĝusta, krom senintence, kvankam eraroj en mezuroj estas kelkfoje tre malgrandaj.

Ekzemple, eĉ post mezuro de kondensatoro, oni povas nur diri, ke ĝia kapacito estas proksimuma. Al tio kontribuas multaj aferoj. Eble eraro dum legado de l'instrumentoj, eble la kapacito de l'kondensatoro mem ŝanĝiĝas kun la vetero, k.t.p. Eĉ la norma kondensatoro ne estas absolute konstanta.

La aŭtoro diras, ke la probabla eraro estas malpli granda, se oni faras kelke da mezuroj de la sama kondensatoro aŭ alia aparato, pro tio ke la meznombro de ĉiuj mezuroj estas pli ĝusta, ol ĉiu individua mezuro. Kiel ekzemplo, li citas ses mezurojn de kondensatoro, unue montrante la mezan kapaciton kaj poste la probablan eraron.

Povas okazi aliaj ekzemploj, ne tiel simple traktebla, ekz., se oni deziras trovi la altfrekvencan induktancon de bobeno. Se la bobeno havus nenian memkapaciton, ĝia induktanco estus trovebla per la formulo de induktanco, kapacito kaj ondlongo. Tamen, ĉar ĝi ja havas memkapaciton, oni devas fari pro tio iom da kalkulado por ricevi la veran induktancon.

OLIVER HEAVISIDE, F.R.S.

[R097

Mallonga skizo pri granda sciencisto, kies laboro dum multaj jarojne ricevis la rekonon, kiun ĝi meritis. Kvankam lia nomo estas mondfama per la esprimo "La Tavolo Heaviside," li estis la unua persono, kiu faris sisteman esploron pri "induktanco," kiun nomon li mem inventis. La termino "reaktanco" ankaŭ estas ŝuldita al li.

Dum sia laborado je fadena telegrafio, li montris, ke oni povas atingi plibonajn rezultojn per arta pliigo de l'induktanco de la linio. Malfeliĉe la telegraf-inĝenieroj en ĉi tiu lando mokis la ideon, sed en Ameriko Pupin disvolvis ĝian praktikan aplikon per helpo de la Amerika Telegrafa kaj Telefona Kompanio, kaj tial la aldonaj bobenoj nun uzataj ricevis la nomon de Pupin anstataŭ de Heaviside.

Honoron oni faris al li, sed treege malfrue. En la jaro 1891a oni elektis lin Fratulo de la Reĝa Societo, kaj en la jaro 1922a li estis la unua ricevanto de la Medalo Faraday.

AMATORA STACIO—2GW.

[R412

Priskribo de tre efika amatora stacio, posedata de S-ro. J. Allan Cash. Li priskribas diversajn antensistemojn, kiujn li provis; la nuna estas kaĝforma kun ses fadenoj, longa 50 futojn, kun 40-futa enirilo ankaŭ kaĝforma; kaj 12-fadena kontraŭpezo.

Multspecajn aparatojn kaj cirkuitojn li utiligis, funkciantajn je ondlongoj de 1 000, 440 kaj 200 metroj.

Sekvas priskribo de la sendilo. La antena kurento estas nur 0·13 amperoj. Li jam trafis ĝis 1 000 mejloj, per enmeto primaria ·11 amp. La unuan nokton li komunikis kun Nederlando, Svedujo, kaj Suda Francujo, je 130 metroj. Kun ·16 amp., tuta Europo ŝajnis esti en lia trafpovo.

Kvankam li posedas du-valvan ricevan aparaton (Detektoro, kaj Malalta Frekvenco), li malofte uzas la duan valvon. Per unu valvo li ricevis multajn amerikajn amatorojn, Argentinan CB8, kaj KDKA.

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Letters of interest to experimenters are always welcome. In publishing such communications the Editors do not necessarily endorse any technical or general statements which they may contain.

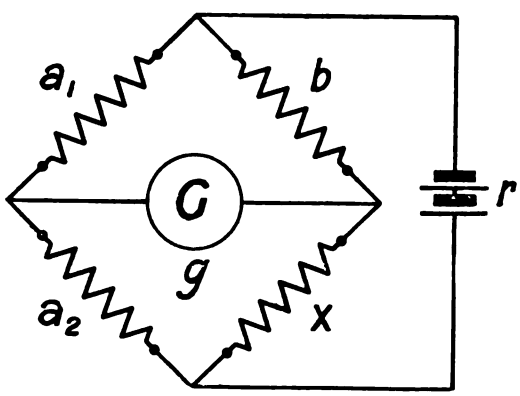
The late Dr. Heaviside's Work.

The Editor, E.W. & W.E.

SIR,—It is pleasant to find in the current issue of E.W. & W.E. an appreciation of the late Dr. Oliver Heaviside. The article contains, however, one slight inaccuracy: Heaviside did not coin the word "reactance." He says (*Electromagnetic Theory*, Vol. I., p. 439): "The word reactance has been lately proposed in France."

By far the greater part of Heaviside's work must remain unknown to all who are not trained mathematicians. But it will be a great pity if his name remains known to the public only in connection with a short paragraph, in an article in an old *Encyclopædia Britannica*, on the possible existence of an electrified layer in the upper air.

Curiously, though Heaviside's work was read by



few of his contemporaries, he was in the first place a great teacher. He taught all who had ears to listen what Maxwell's researches meant in practice.

Among the least mathematical of Heaviside's researches, two ought to be known to every wireless experimenter. His explanation of the action of a permanent magnet in a telephone receiver is embodied in his statement (*Electrical Papers*, Vol. II., p. 156) that the mechanical force on the diaphragm varies as the square of the magnetic force in the gap between magnet and diaphragm. The significance of this fact for broadcast receiving (on account of the multiple forcing of the diaphragm that then prevails) was pointed out last summer in an article on telephone diaphragm resonances in *The Wireless World and Radio Review* by a distinguished authority.

Workers using Wheatstone's bridge may not always realise that when a particular resistance is being measured by this instrument, the various balances that may be obtained differ amongst themselves in point of sensitivity. Heaviside early discussed this matter (*Electrical Papers*, Vol. I., p. 3). As this point is worth attention when careful measurements are being made, and as Heaviside's *Electrical Papers* is a scarce book, it may be permissible to give here the most important of his conclusions:—

a_1, a_2 and b are the resistances of the variable arms; x is the resistance required; g that of the galvanometer and r that of the battery. If a_1b denote the junction of the resistances a_1 and b, and so on, then the battery runs from a_1b to a_2x, and the galvanometer from a_1a_2 to bx. Then the problem is to determine the best values of a_1, a_2 and b, when x, g and r are fixed. "This is the case which occurs so often in practice, when we have a battery, a galvanometer and a resistance to be measured, and three sides of a bridge to which we may give any values we chose (within certain limits)" (*loc. cit.*).

For the best values of a_1, a_2 and b, Heaviside gives

$$a_2 = \sqrt{xr\,\frac{x+g}{x+r}}\,;\ a_1 = \sqrt{gr}\,;\ b = \sqrt{xg\,\frac{x+r}{x+g}}$$

On the subject of the most sensitive condition of Wheatstone's bridge, however, reference should also be made to the late Lord Rayleigh's work (*Collected Papers*, Vol. IV.)

E. N. COLEMAN.

43, Winchester Street, S.W.

Low Power Work.

The Editor, E.W. & W.E.

SIR,—I should be glad if you would publish the following details in E.W. & W.E., which paper I have been a continual subscriber since its inception.

On Sunday, February 1, and at a subsequently arranged test on Sunday, February 8, I worked with G2FN, of Nottingham, during bright sunlight.

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My input was 6 watts—i.e., 300 volts 20mA—to an L.S.1 valve, and aerial current ·25. G2FN reported my signals almost QSA on a single valve, very steady C.W. and easy to read; while G2FN's signals, with a slightly higher radiation, were all over the house on a six-valve superhet on the first occasion; and yesterday, on a two-valve low-loss detector and one stage L.F., were R5.

The following are details of an extremely interesting test which I carried out on February 22 on exceptionally low power and during broad daylight.

At 12 noon, by prearranged schedule, I called 2TF, of Edinburgh, with the same input—6 watts—on C.W. and received a reply immediately. My aerial current was ·15, and 2TF reported sigs. weak, but readable.

2TF was received at my station at R 6 to 4 on a seven-valve superhet, while 2TF was using two valves in his receiver.

The test had been arranged with 2FN, Nottingham, acting as intermediary, but although 2FN and I were in communication I was able to work through to 2TF direct.

After 2FN and I had got into touch, by prearrangement, 2FN switched on to speech and parts of this were received on a loud speaker, but QRM was bad and working continued on C.W. It was after this that I called 2TF, and received acknowledgement of reception of my signals.

I think that this is an exceptional range for such low power as I was using, i.e., six watts.

Incidentally, I have been received by two Finnish stations and all over the Continent on the same six watts at night.

The transmitting valve was an L.S.1 in an inductively-coupled, reversed feed-back circuit.

I put a good proportion of my success down to the inductively-coupled aerial circuit, where the wave is rendered absolutely steady, which is a considerable factor in reading a long-distance signal.

E. J. PEARCEY (2JU.).

Please note new address: 2JU, E. J. Pearcey, 19, Mendora Road, Fulham, London, S.W.6.

Call Signs.

The Editor, E.W. & W.E.

SIR,—The P.M.G. has allocated to me the call sign 5YK in place of my old one, 2AQK, which was issued with a licence for artificial aerial. I shall be very pleased to receive reports on my transmissions, which take place during the week-ends.

G. W. THOMAS.

169, Hill's Road,
Cambridge.

Counterpoise Earths.

The Editor, E.W. & W.E.

DEAR SIR,—I was very much interested in reading the two articles in a recent issue of your journal dealing with the question of the use of "counterpoise earths" for transmission and reception.

Having very carefully read the first, which you endorse as clearing up several doubtful points, I proceeded to act on the advice offered and erected an earth screen.

Using this, I was able to increase the aerial current from 0·4 to 0·8 amps, with the same power input, on a wave-length of 97 metres. It should be mentioned that the effective height of the aerial was reduced from 40 to 32 ft.

Many attempts were made to connect with stations which are usually within easy range, but without success. Various circuits were also tried out but without any improvement. Finally, in complete disgust, I returned to the old circuit with the earth, and with 0·25 amps got a reply to my first call. I am not able at the time of writing to give the QSB of this station, as I have not received his address yet. Judging from the amount of fading, however, he was not within 1 000 miles of me.

This experience may be of interest to Mr. M. C. Ellison, with whom I should like to get in touch if he is prepared to do any further tests on this subject.

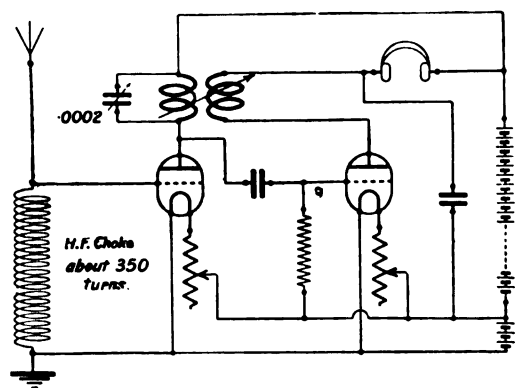
D. DINKLER (2TF).

13, Lockharton Crescent,
Edinburgh.

DX Work.

The Editor, E.W. & W.E.

SIR,—We were seriously thinking of abandoning H.F. amplification below 150 metres for the past DX season when 2OA suggested the employment of an H.F. choke in the aerial circuit instead of a tuned circuit. On trial this was found to give considerably greater signal strength than a tuned circuit.



With the ordinary arrangement, the tuning of the aerial circuit is very broad when reaction is not coupled to it, owing to the high L/C ratio, so little selectivity is lost by using this arrangement as compared to the ordinary H.F. amplifier; and there is a gain as compared to the simple detector valve.

There is only one tuning control, so rapid searching is easy, while, at the same time, there is comparative immunity from jamming.

An ordinary 350 coil works quite well as a choke.

E. C. BULLARD.
M. T. COODE.

Repton, Derby.

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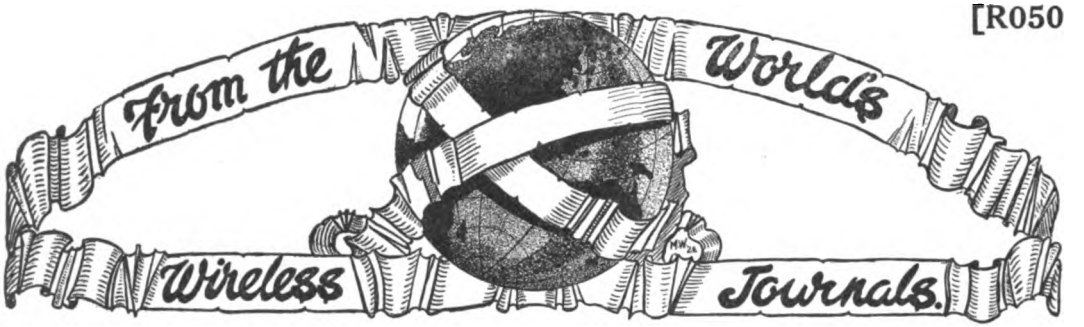
[R050



R100.—GENERAL PRINCIPLES AND THEORY.

R113·3—A Suggestion for Experiments on Apparent Radio Direction Variations.—L. W. Austin (*Proc. I.R.E.*, Feb., 1925).

The author describes briefly some of the effects already discovered in connection with the apparent directional shifts of long-wave stations. He suggests the systematic investigation of apparent shifts in direction as indicated on a frame receiver.

R113·4.—Ionization in the Atmosphere and its Influence on the Propagation of Wireless Signals.—(*Proc. Phys. Soc. Lond.*, Feb. 15, 1925.)

A joint discussion held on November 28, 1924, under the auspices of the Physical Society of London and the Royal Meteorological Society.

A number of papers dealing with atmospheric ionisation, atmospherics, meteorological conditions, terrestrial magnetism and their bearing on the propagation of wireless waves were contributed by Dr. W. H. Eccles, Dr. C. Chree, Dr. E. V. Appleton and Dr. Sydney Chapman. There was also a general discussion. Owing to the large amount of matter involved, an extract cannot be given here, but those interested are referred to the Proceedings.

R113·5.—Recent Investigations on the Propagation of Electromagnetic Waves.—M. Baeumler (*Proc. I.R.E.*, Feb., 1925).

Since the summer of 1922, quantitative measurements have been carried out on the signal strengths of the American high-power stations WQK and WSO, using an objective measuring method. The object of these measurements is to study the propagation of electromagnetic waves. It has been shown that these phenomena can be studied only by continued measurements.

Curves are presented showing the field strengths on three successive days and nights, once each month, for the year February, 1923—January, 1924. In view of the agreement of the calculated values of field strength and the values actually found at night, it is concluded that the night value is to be regarded as the normal one and the day value as the abnormal or disturbed one. An explanation of the diminution of field intensity is given by assuming that the atmosphere is "electrically tubed" by day in consequence of the heating of the earth and the resulting vertical motion of masses of heated air. The waves are refracted, absorbed or reflected (and hence weakened) at the boundary surfaces of masses of different densities. Diurnal and annual variations of field intensity can readily be explained by this theory. It was not possible to establish any difference between field intensity in a large city and in nearby open country.

The derivation of a universally applicable formula giving the field strength, while taking account of all absorption losses, is regarded as impossible at present. The empirically-determined absorption factor of the Austin-Cohen formula does not give results in agreement with measurement, but yields markedly smaller values of field intensity; on the other hand, the absorption factor found by L. F. Fuller gives values in good agreement with the results of measurement.

R113·7.—Daylight Radio Communication Wins.—(*Q.S.T.*, Mar., 1925.)

Some information is given regarding the recent experiments on 20-metre transmission carried out by stations 1XAM, 6TS, 4XE, NKF and others in America. It has been found possible to carry on communication at will over a distance of 1 200 miles in daylight with powers less than one kilowatt. Signals are stronger on 20 metres by day than by night and it was found that signals on 20 and 40 metres faded out during the recent eclipse.

R141·1.—On an Application of the Periodogram to Wireless Telegraphy.—C. R. Burch, B.A., and J. Bloemsma (*M.N.I.R.E., Phil. Mag.*, Feb., 1925).

A mathematical paper discussing the response of a wireless receiver to morse signals and also to atmospherics. The effect of heterodyne detection is examined, and the shape of the resonance curve of the ideal receiver is discussed.

R200.—MEASUREMENTS AND STANDARDS.

R240.—A Method of Measuring at Radio-Frequencies the Equivalent Series Resistances of Condensers Intended for Use in Radio Receiving Circuits.—C. N. Weyl and S. Harris (*Proc. I.R.E.*, Feb., 1925).

The desirability is shown of measuring at radio-frequencies the equivalent series resistance of condensers intended for radio-receiving circuits. For one thing, the power factor of a condenser does not necessarily remain independent of the frequency as is usually assumed. A method of making such radio-frequency measurements is

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set forth in detail, and some preliminary results obtained by the method are shown. One of the tables of results gives a comparison between the old style and "low loss" air condensers. A representative value for the equivalent series resistance at 1 500 k.c. for the old style 500$\mu\mu$F condenser is 0·97 ohm as against 0·73 for the "low-loss" type. Something is therefore gained in the latter, but not much.

R300.—APPARATUS AND EQUIPMENT.

R325·1.—THE MARCONI MARINE RADIO DIRECTION FINDER.—H. de A. Donisthorpe (*Proc. I.R.E.*, Feb., 1925).

A description of the circuits, construction, installation and use of the Marconi Bellini-Tosi marine radio direction finder is given. The method of determining "sense" as well as line of direction of a distant station is explained. The various forms of errors in reading and the methods of reducing or eliminating these are discussed. The paper concludes with a description of a number of cases where the Marconi direction finder has contributed to the safety of life at sea in stormy weather.

R344·3.—RECENT DEVELOPMENTS IN VACUUM TUBE TRANSMITTERS.—B. R. Cummings (*Proc. I.R.E.*, Feb., 1925).

This paper describes a number of valve transmitters recently developed for various commercial and governmental purposes by the General Electric Company of America; it is profusely illustrated with excellent photographs of the apparatus described. A particularly detailed description is given of a 20 kilowatt master-oscillator long-wave C.W. transmitter. Although parts of the paper are interesting as giving an idea of modern radio engineering practice, it seems that the amount of information contained relevant to radio science is not in proportion to the 59 pages which the paper occupies in the issue of the *Proceedings*.

R344·4.—SHORT ELECTRIC WAVES OBTAINED BY THE USE OF SECONDARY EMISSION.—E. W. B. Gill, M.A., B.Sc., and J. H. Morrell, M.A. (*Phil. Mag.*, Feb., 1925).

The grid and plate of a three-electrode valve are connected to adjustable Lecher wires and are given positive potentials with respect to the filament, the potential of the grid being higher than that of the plate. For certain values of emission, applied E.M.F. and adjustment of the Lecher wires, feeble oscillations are sustained which have a wavelength of the order of a metre. If the time taken by the electrons to travel from one electrode to another is comparable with the time of oscillation, the presence of a control electrode may be unnecessary for the maintenance of oscillations. The authors show theoretically how the oscillations are sustained under these conditions.

R388.—A PIEZO-ELECTRIC OSCILLOGRAPH.—C. E. Wynn-Williams, M.Sc. (*Phil. Mag.*, Feb., 1925).

Some experiments were made to determine the possibility of utilising the piezo-electric effect, or rather its converse, exhibited by certain crystals. The effect is the relative movement, linear or torsional, of different parts of a crystal when the specimen is subjected to an electrostatic field in certain directions. The opening part of the paper is devoted to the theoretical considerations of oscillographs in general. It is pointed out that if an oscillograph has a natural frequency of oscillation this should be at least ten times the frequency to be investigated if distortion is to be avoided.

Quartz was tried first, but it was found that the piezo-electric effect was too small. In fact, the change in length of a quartz plate 5 cms long under an applied E.M.F. of 10 000 volts was only just measurable by a delicate method using the interference of light. Next rochelle salt (sodium potassium tartrate) was tried. This was found to be much more sensitive and was embodied in an oscillograph which the paper describes in detail. The electrostatic controlling voltage is applied to a specially prepared and mounted crystal of rochelle salt by means of tinfoil coatings stuck on to the surface of the crystal with shellac varnish or other suitable adhesive. By means of a light aluminium arm the torsional movement of the crystal is made to rotate a small mirror which controls a spot of light in the usual way. It is stated that the oscillograph is simple and compact, working with applied voltages of two or three hundred. Since the resistance of the crystal is very high, it acts almost entirely as an electrostatic device and takes little load from the circuit in which it is included. A newly prepared crystal shows no resonance peak, but crystals which have been in use for some months may show a maximum response as about 3 000 cycles. The method of preparing the crystals is of great importance and details of preparation are discussed in the paper.

R400.—SYSTEMS OF WORKING.

R431.—THE MCCAA ANTI-STATIC DEVICES. PART II.—S. Kruse (*Q.S.T.*, Mar., 1925).

Further practical details of the static-reducing device described in the previous issue are given. Selective devices dependent upon audio-frequency tuning are also described. One interesting arrangement employs a thin strip of soft iron stretched across three bridges, very much after the manner of a sonometer, so that there are two equal sections each capable of vibration at the same audible frequency. One section is in mechanical communication with the movement of a Baldwin receiver actuated by the received signals. The other section of the iron band is connected to a second Baldwin receiver which acts as a generating magnetophone and is connected to an L.F. amplifier. A received heterodyne note of the correct resonant pitch causes the first band section to vibrate, the second band section vibrating in sympathy and causing the second Baldwin movement to generate currents which are amplified. Any aperiodic impulses or currents of the resonant frequency have little effect on the second band section and are therefore not passed on to the amplifier. A further device is described employing audio-frequency tuned transformers.

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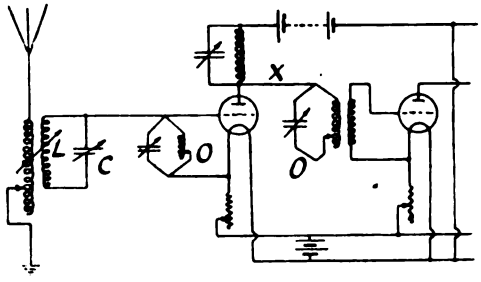
(The following notes are based on information supplied by Mr. Eric Potter, Patent Agent, Lonsdale Chambers, 27, Chancery Lane, W.C.2.)

[R008

A SYNTONIC "REINFORCER."

(Application date, June 20, 1923, and February 1, 1924. No. 223,625.)

THE above British Patent, due to Sir Oliver Lodge and E. E. Robinson, is illustrated by the accompanying diagram. The invention lies in the use of a free uncoupled low resistance oscillatory circuit which in the words of the specification is "stimulated by oscillations from any source or from any



place where oscillating currents are passing . . . to work up oscillations of one definite frequency into considerable amplitude by sympathetic resonance." An important feature of the invention is that the "generator" or syntonic "reinforcer" must not be coupled to any tuned circuit in which oscillations are generated. Thus in the illustration LC represents the closed circuit of the tuning system. The special tuned circuit of low resistance is shown as O. Two "O" circuits are shown, the first being connected across the grid circuit of the first valve; the second circuit is used in conjunction with a tuned anode circuit, the oscillations being stimulated in it merely by being connected to the wire X. In this particular case the "O" circuit is coupled to the grid circuit of the next valve in the ordinary manner.

IMPROVED VALVE CONSTRUCTION.

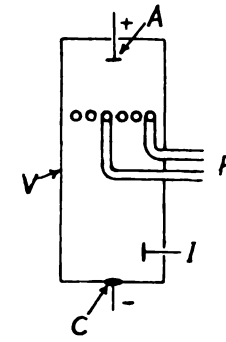
(Application date, July 18, 1923. No. 223,306.)

H. J. Osborn and W. L. Turner describe in the above British Patent a system of valve construction employing alloys of chromium. It is stated that if certain chromium alloys are used for making the anodes and grid of valves, the cost of construction is materially lessened, as they are easier to work and also require no subsequent treatment for the release of occluded gas. An alloy which gives satisfactory results is an iron chromium alloy containing from 9 to 20 per cent. of chromium and less than 0·5 per cent. of carbon. It is further stated that an alloy of this type may be used for the filaments of dull emitter valves.

A MERCURY VAPOUR DISCHARGE DEVICE WITH A CONTROL ELECTRODE.

(Application date, October 12, 1923. No. 226,902.)

Dr. H. Konemann describes in British Patent No. 226,902 a rather interesting form of mercury valve lamp. The specification points out that with the ordinary three-electrode valve it is impossible to control a very large amount of current. In the case of the discharge device, such as a mercury tube, the conductive value of the ionic current is considerably greater than that of the ordinary electronic stream on a three-electrode valve. According to this invention, which is illustrated diagrammatically by the accompanying sketch, the control electrode is arranged as follows: The discharge device is contained within a vessel V provided with two electrodes A and C. The starting, or ignition, electrode I is also shown. The grid, or control electrode, takes the form of a tube P. It has been found that if an ordinary grid is interposed between the electrodes, small drops of mercury are liable to form on the grid and interfere with the function of the device. This difficulty is overcome by passing a stream of hot air through the tube. It seems to us that there are considerable possibilities in a device of this description, and should prove excellent subject matter for amateur experimental work.



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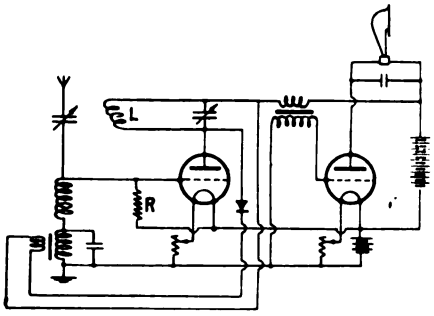
A REFLEX CIRCUIT.

(*Application date, June* 27, 1923. *No.* 226,843.)

The accompanying diagram illustrates one of the many types of reflex circuits, which in this case is claimed by J. Scott-Taggart, in British Patent No. 226,843. The mode of operation of the circuit should be obvious enough to require but little description. Essentially it consists of a high frequency amplifier operating on the tuned anode principle with a crystal rectifier, the rectified current from which is re-amplified by the first valve, whose output circuit is connected to a straight note magnifier. Several other modifications are shown in the specification, and the following are some of the chief claims: The first claim of the specification is for a reflex circuit with direct aerial coupling, in which the intervalve transformer is



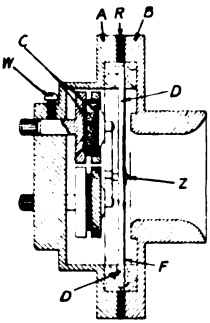
connected between the earth and the lower side of the aerial circuit. This seems to us rather an obvious thing to do. A claim is also made for shunting the secondary of this transformer with the condenser, which also would be expected. Another claim is made for the use of a crystal detector in conjunction with an intervalve transformer, both being connected across the tuned anode circuit. A further claim is made for the use of a resistance (marked R in the illustration) of about 100 000 ohms connected between the grid of the first valve and preferably the positive side of the filament battery. The object of this resistance is apparently to stabilise the circuit by increasing the damping. In another modification of the circuit, not illustrated, the second valve is used as a rectifier, in which case the telephone or loud-speaker is connected directly to the anode of the first valve. A claim is also made for the use of a choke coil in this circuit.

In view of the large amount of work done on such circuits from 1913 onwards, we doubt as to the validity of such claims as late as 1923.

AN IMPROVED MICROPHONE.

(*Application date, July* 25, 1923. *No.* 223,658.)

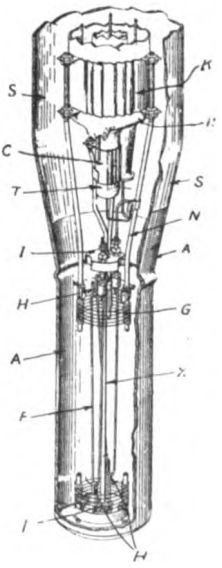
E. A. Graham describes in British Patent No. 223,658 an improved form of microphone, which is illustrated in the accompanying diagram. The novelty of the invention lies chiefly in providing a damped diaphragm, comparatively thick in relation to its diameter and with one or more microphone buttons attached to it. Referring to the illustration, it will be seen that the microphone itself is housed within a casing, which is made of two parts A and B, which are conductively separated by an insulating ring R. The thick diaphragm D is attached to a strip of metallic foil F by a washer and nut N, the strip being clamped between two halves of the casing. The diaphragm is damped on either side by a quantity of non-sonorous material, such as "Sorbo" rubber, arranged in annular formation. The microphone buttons are quite normal, and consist of two carbon plates C, with a quantity of granules between them. The button is held in the back of the casing by means of a rod which passes through a longitudinal slot provided w.th a clamping screw W. The other side of the button is attached to the diaphragm by means of a metal link. The specification provides for the use of a number of these buttons, which are linked together by means of a suitable yoke which is attached to the diaphragm.



AN EXTERNAL ANODE VALVE.

(*Application date, September* 27, 1923. *No.* 214,192.)
(*Convention date, United States, April* 13, 1923.)

M. J. Kelly and the Western Electric Company, Ltd., describe in British Patent No. 214,192 the construction of a high power external anode valve. The accompanying illustration shows diagrammatically its general form. An anode A is fused to a glass portion S, the end of which is not shown in the diagram. Fused to the glass portion S is a re-entrant tube R, and, arranged co-axially within the re-entrant tube, is another tube T. The re-entrant tube R is used to support the grid, while the small tube is used to support the filament. A collar K is frictionally held on to the tube R. This collar supports three rods N, around which the grid G is formed. Another collar C is fixed in a similar manner to the tube T, and this collar supports a rod X. Fixed to each end of the rod X are two insulating members I, which are held in position by means of nuts. These blocks carry a number of hooks H, to which the filament F is attached. The leads from the grid and the filament are brought through the concentric tubes.



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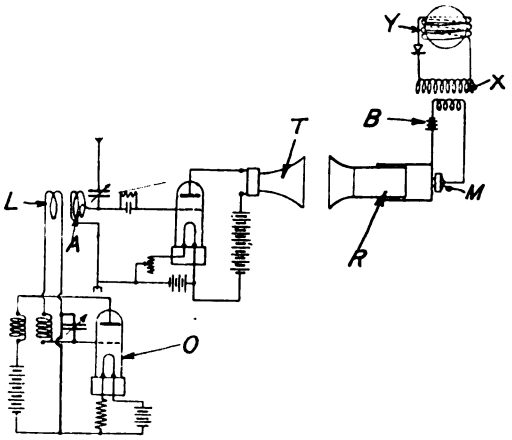
A VICKERS' WIRELESS CONTROL SYSTEM.

(*Application date, August* 22, 1923. *No.* 224,318.)

Captain C. B. Ryan and Vickers, Ltd., describe in British Patent No. 224,318 a system of control which is illustrated by the accompanying diagram. The invention relates to systems of control which function by virtue of periodic impulses of predetermined frequency. According to this invention the received signals are heterodyned by a local oscillator O, provided with a coil L coupled to an aerial coil A. The output circuit of the receiving system includes a telephone or loud-speaker. The frequency of the control signals is set within very fine limits, as is also the frequency of the

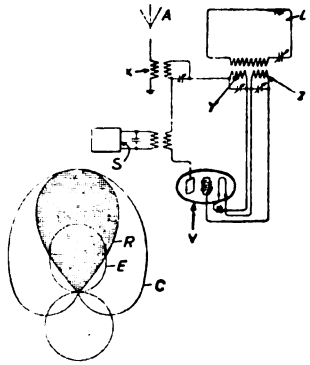


local oscillator. This ensures that the resultant heterodyne beat note of the signals is perfectly constant. In front of the telephone or loud-speaker is an acoustic resonator R, at the end of which there is a microphone M provided with a local battery B and a transformer X, which is connected to a tuned oscillating device Y. It will be seen that this system of control is very accurate in operation, and could only be rendered inoperative with the greatest difficulty. In the first place, the heterodyne beat note would have to be exactly duplicated; secondly, the impulse period has also to be found. Even if the exact H.F. component were discovered, this would be of no use without the group frequency as well, since the operating device Y is an arrangement such as a spring controlled weighted wheel, which has a natural frequency equal to that of the group frequency of the signals.

SELECTIVE RECEPTION.

(*Convention date, United States, May* 11, 1923. *No.* 215,787.)

British Patent No. 215,787, assigned to The British Thomson-Houston Co., Ltd., by E. F. W. Alexanderson, describes a selective system of reception depending upon directional aerials. The accompanying diagram illustrates both the circuit employed and also the receiving diagram. It is well known that the receiving diagram of a plain vertical loop resembles a figure "8," as shown by E, while when combined with an ordinary open aerial, a heart-shaped or cardioid loop C results. In this arrangement, however, it will be seen that a



vertical aerial A and a loop aerial L are provided. Two high frequency coupling transformers X and Y are used to couple both the frame and the open aerial to the anode circuit of a valve V. In addition, another coupling transformer Z is coupled to the frame L and is connected to the grid circuit of the same valve. The anode circuit of the valve is connected to a receiving apparatus S. The receiving diagram which results from this combination is indicated by the shaded area R, and is obviously quite different from that obtained merely by vectorial addition. It will be seen that it is a maximum in the direction that the cardioid and figure "8" have their maxima. In a direction ninety degrees from this position it is zero, because the figure "8" is zero; and in a direction one hundred and eighty degrees from its maximum, it is also zero, because the cardioid is zero in that direction. The resulting diagram resembles one which would be obtained from a wave-aerial one wavelength long. The specification also provides for combining the resultants of two such systems through a third phase selector, which thereby gives even greater directivity.

AN AUDIO-FREQUENCY AMPLIFIER.

(*Application date, May* 16, 1923. *No.* 220,381.)

E. A. Graham and W. J. Rickets describe in British Patent No. 220,381 a form of audio-frequency amplifier which is illustrated by the accompanying diagram. It will be seen that the anode circuit of a valve V contains the primary winding of an intervalve transformer T. The secondary winding of the transformer, instead of being connected to the grid and filament of the subsequent valve, is connected between the grid and a grid-leak R, the usual bias battery B being provided. A condenser C is connected between the anode of the first valve and the lower side of the secondary winding of the intervalve transformer. Another condenser K is also shown but in reality it is merely connected across one of the high tension batteries, separate batteries being shown. The

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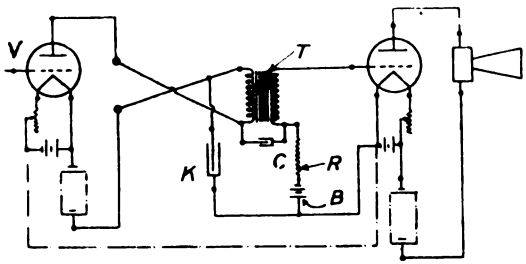
specification states that the arrangement gives a higher degree of amplification than is obtainable with the more usual arrangement. How far this statement is justified it is impossible to say without

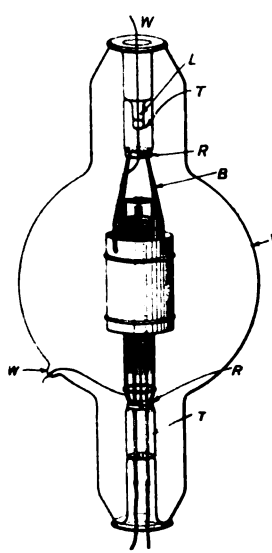


analysing the circuit mathematically, but it seems highly probable that this may be the case. From a practical point of view, the circuit should prove of interest to experimenters.

VALVE CONSTRUCTION.

(*Convention date, Holland, October* 21, 1922. *No.* 205,784.)

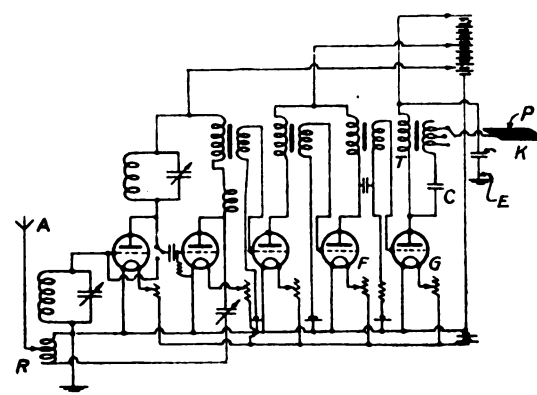
Naamlooze Vennootschap Philips' Gloeilampenfabrieken describe in British Patent No. 205,784 an interesting form of valve construction which is illustrated by the accompanying diagram. The object of the invention is to provide primarily a simpler form of mounting for the electrodes and also a method which overcomes many disadvantages which are inherent with the existing methods. Hitherto the grids and anodes have been welded to some form of collar which has been tied, or screwed on either directly to a tube, or by means of lugs on the tube. One of the disadvantages of this method is the comparative difficulty in freeing the supports from occluded gases. According to this invention, the envelope of the valve V is provided with a tube T, to which is fused a ring R. This ring is made of some alloy which has a co-efficient of expansion equal to that of the glass tube. A chrome iron alloy, containing from 10 to 50 per cent. of chromium, is mentioned as being suitable. The illustration shows the relatively small size of the ring compared with the more normal collar. Another feature of the invention is the provision of bars B, which support the electrode, but do not serve as the leading out wires. The leading out wires W are welded to the bars B and are brought out of the valve in any convenient manner. One method of doing this is claimed in the specification, and consists in closing the hollow tube with a glass portion L, through which the wire passes. The patent specification is very detailed and contains many simple but ingenious points.



A PECULIAR RECEIVING SYSTEM.

(*Application date, June* 25, 1923. *No.* 223,630.)

A rather extraordinary system of reception is detailed in British Patent No. 223,630 by G. W. Hale and R. Lyle. The accompanying illustration shows one of the circuits given in the specification. The chief object of the invention appears to be that of providing a means for receiving wireless signals without connecting the telephones to the set. Referring to the illustration, the first part of the receiver appears to be a rather unusual form of high frequency amplifier and detector in which the aerial A is connected to a shunt reaction coil R. The remaining three valves act as ordinary audio-frequency amplifiers except that the valve F is coupled to valve G in exactly the same manner as that described in specification No. 220,381



detailed above. The anode circuit of the last valve G contains a transformer T, which is tapped on the secondary, one side of the secondary being connected to the anode through a condenser C. A condenser K is shown connected between the earth and the low potential side of the primary winding of the transformer T. It is not quite clear if the earth connection shown at E is the same as the earth of the set, but if so, the condenser K is simply connected across the high tension battery. The tapped transformer is shown connected to an object P. This object P is a mesh or network of wires which, it is stated, can be placed between sheets of rubber, or stout paper, and concealed under carpets, or suspended beneath ceilings or similar inconspicuous places. It is stated that an intense electrostatic field is set up between the meshes and the earth. Further, it is stated that if a pair of insulated conductors is placed in the field, having unequal capacities to earth, a potential will be set up between them, and if the telephones be connected to them they will be rendered operative. The

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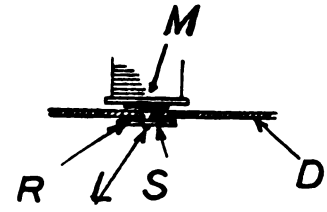
specification also describes and claims a form of telephone which is essentially of the pot magnet type.

Ingenious as the scheme may be, we ourselves prefer to connect our phones to a receiver by means of two terminals !

A DAMPED DIAPHRAGM.

(*Application date, June* 13, 1923. *No.* 222,174.)

A. F. Sykes describes in British Patent No. 222,174 (which is one of a series of his patents relative to diaphragms), an interesting form of damping. The specification relates to diaphragms of all types and for all purposes; the modification most suited for telephones or loud-speakers being shown in the accompanying illustration. An ordinary diaphragm D is shown adjacent to the electromagnet M. A damping plate S is attached to the centre of the diaphragm by means of a portion L—the space between the damping plate S and the diaphragm being filled with some non-sonorous substance such as vaseline, oil, petroleum jelly, or even rubber. Many modifications are described in the specification, including a composite,



laminated, corrugated diaphragm, in which the corrugations are separated by a non-resonant substance. It seems that the specification contains considerable subject matter of interest to amateur experimenters.

SOME CORRECTIONS.

Unfortunately one or two clerical errors appeared in our last issue, and we shall be glad if readers will note them.

(1) Owing to a re-arrangement at the last moment, the words "by F. M. Colebrook" on the cover came above instead of below "The Rectifying Detector." It is, of course, the latter article which is by Mr. Colebrook, not the obituary note on Heaviside.

(2) Some Dewey Index numbers were omitted. They should be inserted as follows :—

P. 354	Series-parallel Switch	R387
P. 363	Valve Designations	R130.30
P. 365	The Wireless Bill	R007.5
P. 367	New Valves Tested	R333.009
P. 369	Some Fixed Condensers	R381.009

(3) In the article on Error in Measurements (p. 360), the calculation given for finding the "probable error" actually finds what is known as the "*mean* error." We need not go into detail as to the distinction : the probable error is got by multiplying the mean error (as found by the method given) by two-thirds. In the example given, the probable error of a single reading will be 3·23, and that of the average 1·29 ; the percentage will be ± 0·87 per cent.

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EXPERIMENTAL WIRELESS & The WIRELESS ENGINEER

VOL. II. MAY, 1925. No. 20.

Editorial Views.

The Paris Conference.

THE conclusions reached at the International Conference of Amateurs, held just after Easter at Paris, will, we are sure, be of great interest to our readers. In a later issue we hope to reproduce at some length the actual resolutions expressed; here we propose to give just a short *résumé* of the work done.

Five matters were put up for discussion :—

A. A proposal for an International Amateur Radio Union ;

B. Arrangements for International tests, etc. ;

C. Allotment of definite wave-bands for international amateur work ;

D. An international auxiliary language for amateurs ;

E. Arrangements for the use of definite intermediate letters to indicate country.

Each of these questions was considered by a separate sub-committee, containing delegates from the countries represented at the Conference, except question A, which was considered by the whole. The resolutions of the sub-committees were reported to and considered by the whole Conference.

The I.A.R.U.

A complete draft organisation for this was submitted by the A.R.R.L., and after considerable modification many parts of it were adopted. One or two of the outstanding points of the final scheme are : Membership will be open to any person seriously interested in amateur experimental wireless work. If there are not less than 25 members in a country, a national section will be formed. Each such section will have a "national president." There will also be a President, Vice-President, and Secretary-Treasurer at headquarters, also an Executive Committee. For the present, headquarters will be the headquarters of the A.R.R.L., and "Q.S.T." will be the official organ. The annual subscription will be $1. Twenty-one countries were represented in the voting.

International Tests.

The sub-committee on this question considered that the matter needed more detailed investigation than could be given in the time available. They therefore only gave general recommendations. They suggested that a representative should be appointed to go into the question in each country, and report to headquarters. They suggested a definite scheme for arranging the time for scheduling tests, this being to specify G.M.T., and give the time in the four-figure form, from 0000 to 2359. They also hoped for a definite scheme for rating signal-strength. Lastly, they suggested a definite schedule of times permanently allotted for communication with headquarters.

Wave-bands.

This sub-committee devoted much thought to getting out a schedule of wave-lengths which should be (*a*) within the licensed bands for each country's transmitters ;

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(*b*) suitable for International work. They finally specified the following :—

Country.	Usual Band	Extra short band
	Metres.	Metres.
Canada and Newfoundland ..	120-115	43-41.5
Europe	115-95 75-70	47-43
Other parts (except as below)	95-85	37.3-35
U.S.A.	85-75	41.5-37.3

They suggested that amateurs should use other waves within their licensed bands for near communication, reserving these exclusively for International work. They hoped that the I.A.R.U. would be able to set up an International standard.

International Language.

This sub-committee recommended Esperanto as a standard auxiliary for telephony, for abstracts and/or translations in periodicals, and for congresses. It suggested the same for telegraphy where the two workers had no common national language. The Congress also adopted it as its own auxiliary language, besides the national languages used. The Committee very thoroughly considered the claims of the languages proposed to it for the purpose (English, Esperanto, Ido and Interlingua), but was definitely in favour of Esperanto.

Intermediate Call Letters.

The sub-committee on this subject got out a complete list of letters to replace the official DE and give the countries called and calling. We do not give these *in extenso* at present, as in any case their use is illegal in Great Britain.

They also quoted the initial figures of call-signs in various European countries (*e.g.*, 2, 5 and 6 for Great Britain ; 8 for France, etc.) and asked the I.A.R.U. to persuade governments, if possible, to consent to numbers on a consistent scheme thus :—

1	Italy
2, 5, 6	Great Britain
3	Finland
4	Germany
5	(See 2)
6	(See 2)
7	Denmark
8	France
9	Switzerland
0	Luxemburg.

Power Loss in Coils.

We are very pleased, and we are sure our readers will be also, to have, in the article by Mr. R. M. Wilmotte in this issue, some definite information as to the relative importance of various points in the design of coils. It is true that the question of power loss in coils is so complicated that one cannot give absolutely simple, easy and definite instructions on avoiding them while at the same time making a reasonably cheap and compact coil.

But there is room for improvement on the lines indicated. It is only a few months ago that we saw a commercial set in which, for compactness, the variable condensers were put inside the coils !

It is evident from the results obtained in Mr. Wilmotte's tests (conducted with the facilities of a great laboratory) that the question of the insulation between turns is of paramount importance. He found especially that cotton covering was to be avoided, and in cases where the turns are in contact the increase in resistance will be even greater than in the case quoted by him. It is obvious that the general lines of design for short-wave coils—including those for broadcast wave-lengths—must be : increase of air-space between turns, even at the cost of using thinner wire ; use of the minimum amount of "building" material (*i.e.*, solid insulating formers, etc.), near the wires ; choice of good insulating materials.

Detectors.

In this issue we conclude the article by Mr. F. M. Colebrook on the crystal detector. We hope that even those of our readers who are not disposed to journey with him through the by-ways of mathematics will none the less note carefully his conclusions, especially those showing that under proper conditions the crystal detector is a distortionless rectifier of high efficiency. We have in hand a further article by the same author, in which similar methods are applied to the consideration of the valve detector ; and we may say at once that this article confirms our own opinion that the crystal is superior, at any rate for telephony. It would seem likely that the most efficient combination of all is that of an H.F. valve with reaction, followed by a crystal, with a separate heterodyne for C.W. work. Of course, for many purposes this is too complicated, so a less efficient design must be used.

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A Calibrator's Day. [R2083

Some of our sorrows. Perhaps a careful perusal of them will persuade readers to help us more in future

WE wonder whether a few readers might derive some useful lessons from the simple report of a day's work in the calibration department!

Anyhow, we are going to inflict it on them, for we ourselves have feelings, and at the moment of writing they need relief. It had happened that our calibration work, which is usually done in the evening, had been getting in arrears, so we decided that two of us should put in a full day at it and clear some of it off. So at 9.30 a.m. we started, full of hope, and rigged the standard valve wavemeter in one corner of the room and the buzzer in the other. And these were the first 15 instruments we handled :—

1. A valve wavemeter.—Two ranges, claimed to be 40-250 metres. Its appearance was not hopeful, for the coils were wound on cardboard formers, so that their inductance could not be depended on to remain constant nearer than, say, 2 per cent. It had the favourite but horrible scheme of connections shown in Fig. 1, which is very liable to change of wave-length owing to the phones and H.T. battery being inserted at a high-potential point. However, we connected it up, and spent half an hour trying to get in touch with it. Finally, having proved that not even the substitution of 100 volts for the specified 30 would make it oscillate on the short range, we turned it down.

2. A variable condenser.—The owner had had a good idea in using a protractor as a 180 deg. scale, with a pointer on the spindle. This was soon done.

3. Another variable condenser, this time with transparent celluloid housing. The job was soon done, but we wonder whether the user will realise that (owing to the absence of shielding) the act of putting the condenser within a foot of the rest of any circuit will upset all the readings we gave him? Metallic cases are essential for condensers to be used in quantitative work.

4. A similar job to No. 3.

5. A valve wavemeter, obviously made on the same design as No. 1 (from an article that appeared in a well-known wireless periodical some months ago). For results, re-read above paragraph, except that we gave it up after a quarter of an hour instead of half.

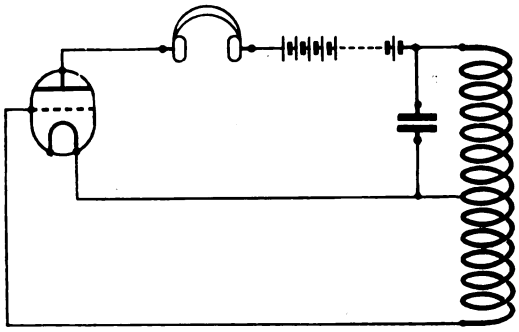

Fig. 1.

6. A different type of valve wavemeter, and, to our joy, preliminary tests showed oscillation over both its ranges! A few tests with the standard at 5 000 metres or so (see "Harmonics," E.W. & W.E., April, 1925, page 390) established the fundamental, and this job was soon done.

7. Two plug-in coils, for inductance and self-capacity. Soon done. They were of a good type for measurement, being single-layer coils on good rigid formers.

8. A buzzer wavemeter.—Quite O.K., and soon done.

9. Another buzzer, but this time of the more usual type, *i.e.*, with non-buzzing buzzer. However, 20 minutes' work put this right, and the meter itself was not unduly flat. But why do people wind buzzer shunts of wire on matchsticks, when a miniature lamp is such a superior alternative?

10. A set of boxed condensers, including one variable.—Why, oh, why, do people pick

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out, for standardising purposes, a variable condenser of the varying-distance type, with a characteristic curve like Fig. 2 ? Especially when it is practically certain that in a few months said condenser will develop backlash and be subject to 10 per cent. error in the all-in position !

A curious point about this test was that one of the fixed condensers (rated .000 5) showed .000 004. Was it, we wonder, a dud condenser ? Or did the builder forget to connect that one ? Or can't he solder ?

11. A beautifully-built buzzer wavemeter. Gave quite good results on its first range, but exactly the same wave-length on the

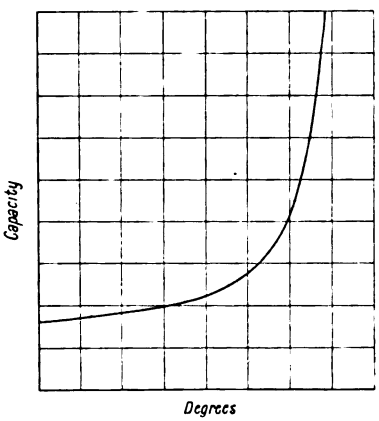

Fig. 2.

second, third and fourth ranges. Evidently the builder forgot something—or was it, perhaps, a practical joke ? If it was, we failed to see the point.

12. A valve wavemeter, built by a wireless firm for a customer, to whose design it is not stated ; anyway, it would only oscillate on the middle one of its three ranges, so was turned down. We hear that the firm who built it has gone out of business. This causes us neither sorrow nor surprise.

13. Three small fixed condensers, for a commercial firm. An easy job.

14. A valve wavemeter, of similar design to Nos. 1 and 5. This has a history. It first arrived with some of the components and most of the tin-foil shielding in a sort of salad loose in the case. We sent it back. This time it was more or less in one piece. But a fixed condenser was designed to be held in place only by its connecting wires, and the maker was no artist with the soldering iron. Result may be guessed. We were preparing to repair this, to avoid having to return it again, but just then we noticed that turning the condenser knob had no effect on the plates. So that was turned down. Two useful notes : (*a*) If apparatus has to be sent by rail or post, fix the components. (*b*) For an instrument to be calibrated, pin the knob or pointer through the spindle ; lock-nuts are not good enough.

15. A buzzer wavemeter. Quite all right in design, as far as we could tell. But we could not be sure, for the variometer had ten degrees backlash between rotor and knob, and there were three disconnections in the circuit.

At this point our feelings overcame us. We adjourned for tea, and deferred further calibration to a later date.

The Lesson.

We have tried to treat of our day's work in a spirit of resignation tempered by mild humour. But there is a serious side to it. Out of 14 instruments for readers, 7 (50 per cent.) could not be calibrated on account of glaring faults. Of the remainder, 4 (28 per cent.) were calibrated, but were not really suitable, and probably will not maintain their accuracy ; leaving 22 per cent. (3 out of 14) really satisfactory. Out of eight hours' work, about four and a half hours was wasted—for it takes longer to " mess about " with a bad instrument than completely to calibrate a good one.

May we beg readers who are making instruments for calibration to adopt the following hints :—

1. Get a decent design to start with.

2. Use reasonably good components ; *especially spend all you can afford on a good condenser.*

3. Put just a little care into construction.

4. Test the instrument, and *prove* that it works properly before sending it.

5. Pack it properly for transport.

6. Give us the information asked for in the page containing the coupon.

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The Rectifying Detector.

By F. M. Colebrook, B.Sc., D.I.C., A.C.G.I.

Part III and Last. [R149

An exhaustive investigation, theoretical and experimental, into one of the most difficult problems of the Wireless Engineer.

9. Efficiency in the Rectification of a Modulated High-Frequency E.M.F.

We are now in a position to consider the variation of the modulation frequency power obtained, with the magnitude and character of the load. From equation 8·13 the amplitude of $\mathbf{I}_n$ is

$$I_n = \frac{K_c R_{cm} M}{\sqrt{(R_{cm}+R_n)^2+X_n^2}} \quad .. \quad (9\cdot1)$$

It will be convenient to assume some constant mean value for the ratio of M to E. Calling this μ we have

$$I_n = \frac{\mu K_c R_{cm} E}{\sqrt{(R_{cm}+R_n)^2+X_n^2}} \quad .. \quad (9\cdot2)$$

Expressing this in terms of Z_n and θ

$$I_n = \frac{\mu K_c R_{cm} E}{\sqrt{Z_n^2+2R_{cm}Z_n\cos\theta+R_{cm}^2}} \quad (9\cdot3)$$

An obviously important factor is the ratio of Z_n to R_{cm}. Calling this ν then

$$I_n = \frac{\mu K_c E}{\sqrt{\nu^2+2\nu\cos\theta+1}} \quad .. \quad (9\cdot4)$$

The modulation frequency power is therefore

$$P_n = \frac{\nu\cos\theta}{\nu^2+2\nu\cos\theta+1}\;\frac{\mu^2 K_c^2 E^2 R_{cm}}{2} \quad (9\cdot5)$$

For the sake of simplicity we will consider first the case in which the amplitude E can be considered constant. This will correspond approximately to any case in which, by valve retroaction or other means, the damping effect of the detector load can be neutralised. In all such cases the most important factor will be

$$\Psi(\nu,\theta) = \frac{\nu\cos\theta}{\nu^2+2\nu\cos\theta+1} \quad .. \quad (9\cdot6)$$

The form of this function for $\theta = 0$ and $\theta = 60^\circ$ is shown in Fig. 28. For any constant value of θ it reaches a maximum when $\nu = 1$, its value being then

$$\Psi(\nu,\theta)_{(max)} = \frac{\cos\theta}{2(1+\cos\theta)} \quad .. \quad (9\cdot7)$$

Again, the expression on the right hand side of equation 9·7 reaches a maximum value when $\theta = 0$, its value being then $\frac{1}{4}$. This, therefore, is the maximum-maximum value of $\Psi(\nu,\theta)$. The corresponding value of P_n is

$$P_{n_{(max)}} = \frac{\mu^2 R_{cm} K_c^2 E^2}{8} \quad .. \quad (9\cdot8)$$

On the assumption of a constant input potential, therefore, the proper basis for the comparison of detectors is $K_c^2 R_{cm}$.

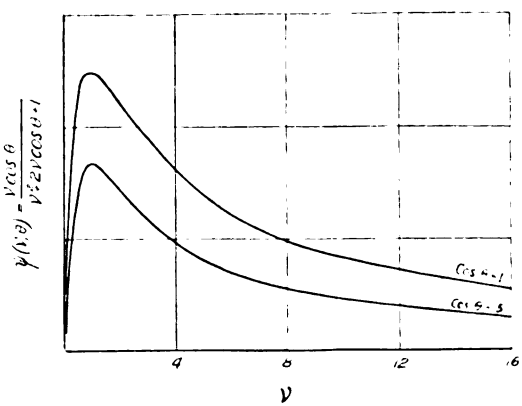

Fig. 28. *Variation of audio-frequency output power with load, for constant input volts.*

The determination of this quantity is considered further on.

The discussion of the condition for the maximum efficiency of conversion of high-frequency power into modulation frequency

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power, which is the more important characteristic in relation to the direct reception of modulated continuous waves with a crystal detector, is very much more complicated. In the first place, it must be remembered that the E.M.F.

$$e = (E + M \sin nt) \sin \omega t \qquad .. \quad (9{\cdot}9)$$

is really equivalent to three continuous waves having frequencies $\frac{\omega}{2\pi}$ and $\frac{(\omega \pm n)}{2\pi}$ respectively. Thus, even in the case of a single pure tone modulation the expression for the high-frequency power will be a complicated one. However, since M is in general very small compared with E, the high frequency power consumed will only differ very slightly from that in the case where the E.M.F. is unmodulated and of frequency $\omega/2\pi$ and amplitude E. The power P_1 can therefore be calculated on this basis and expressed in the form

$$P_1 = \frac{E^2}{2R_1} \qquad .. \quad (9{\cdot}10)$$

where R_1 is the effective high-frequency resistance of the detector circuit under any given load condition. The efficiency of conversion can therefore be put in the form

$$\eta = \frac{\nu \cos \theta}{\nu^2 + 2\nu \cos \theta + 1} \mu^2 K_c^2 R_1 R_{cm} \qquad (9{\cdot}11)$$

As has been shown in an earlier part of the paper, R_1 will vary considerably with R (the D.C. resistance of the modulation frequency load), increasing rapidly as R increases. This increase of R_1 may, and in most practical cases actually will, more than compensate for the decrease in $\Psi(\nu,\theta)$ due to the consequent increase of ν, the ratio of Z_n to R_{cm}. The matter cannot be very usefully discussed without reference to actual values, and will therefore be considered more fully when discussing experimental results. It may be stated, however, that in general the best load resistance will be in excess, in some cases very greatly in excess, of the value apparently appropriate to the internal resistance of the detector. This is probably the reason for the greater sensitivity obtained by the use of high resistance telephones in the direct crystal reception of modulated continuous waves, in spite of the fact that the impedance of such telephones at audible frequencies will be greatly in excess of the apparent internal resistance of the detector.

Experimental Results with Modulation Loads.

It has been shown that the modulation power developed in a load of magnitude Z_n and phase angle θ_n due to the rectification of an E.M.F. E, where

$$e = (E + M \sin nt) \sin \omega t = E(1 + \mu \sin nt) \sin \omega t,$$

will be

$$P_n = \frac{\nu \cos \theta_n}{\nu^2 + 2\nu \cos \theta_n + 1} \frac{\mu^2 K_c^2 R_{cm} E^2}{2}$$

where $\nu = Z_n / R_{cm}$.

It was further shown that

$$\frac{1}{R_{cm}} = F_1(E) - v_0 F_2(E) + \frac{v_0^2}{2!} F_3(E) - \ldots$$
$$+ (-1)^n \frac{v_0^n}{n!} F_{(n+1)}(E) + \ldots = -\left(\frac{\partial i_0}{\partial v_0}\right)_E$$

and that

$$\left(\frac{\partial i_0}{\partial E}\right)_R = \frac{K_c R_{cm}}{R_{cm} + R}$$

where

$$K_c = F'(E) - v_0 F_1'(E) + \frac{v_0^2}{2!} F_2'(E) -$$
$$\ldots + (-1)^n \frac{v_0^n}{n!} F_n'(E)$$

The values of the quantities K_c and R_{cm} can thus be determined either from the known form of the characteristic or, if this cannot be expressed in mathematical form, from the measurement of the slopes $(\partial i_0/\partial E)$ and $(\partial i_0/\partial v_0)$. It is clear that the values will depend primarily upon E, and for a given value of E will vary somewhat with R, the D.C. resistance of the modulation frequency load. If R is very small, v_0 will be small, and we shall have

$$K_c = F'(E)$$

$$R_{cm} = R_c = \frac{1}{F_1(E)}$$

For finite values of v_0, K_c will in general decrease in value, while R_{cm} will increase, the product $K_c R_{cm}$ varying less than either of them in consequence. The values of R_{cm} for a constant load of 1 000 ohms are shown in Fig. 29 for the two types of detector. It will be seen that the curves are very similar to those showing the variation of

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R_c with E. The values of R_c, which are very simply determined in the manner already described, can, in fact, be taken as an indication of the values of R_{cm} with the understanding that for moderately large carrier wave amplitudes R_{cm} may increase with R up to something like twice its no-load value. The following table will give a general idea of the order of magnitude of R_{cm} and K_cR_{cm} and the nature of their variation with R.

GALENA.

E	R =	0	200	400	600	800	1 000
·9	R_{cm} =	90	140	150	95	60	50
·9	K_cR_{cm} =	1·1	1·1	1·1	·97	·86	·80
·5	R_{cm} =	120	143	228	270	274	250
·5	K_cR_{cm} =	1·1	·80	·87	·87	·92	·99
E	R =	0	1 000	2 000	3 000	4 000	5 000
·1	R_{cm} =	3 200	3 800	4 300	4 800	5 200	5 600
·1	K_cR_{cm} =	1·17	1·26	1·36	1·45	1·54	1·61
·05	R_{cm} =	7 060	7 160	7 200	7 250	7 260	7 300
·05	K_cR_{cm} =	·665	·650	·640	·630	·620	·610

PERIKON.

E	R =	0	500	1 000	1 500	000	3 000
·9	R_{cm} =	380	540	650	700	760	790
·9	K_cR_{cm} =	·76	·95	·98	·98	·97	·94
·5	R_{cm} =	560	640	730	920	1 080	900
·5	K_cR_{cm} =	·80	·70	·80	·85	·80	·67
E	R =	0	1 000	2 000	3 000	4 000	5 000
·1	R_{cm} =	12 000	12 500	13 000	13 500	14 000	14 800
·1	K_cR_{cm} =	·77	·79	·81	·83	·86	·88
·05	R_{cm} =	17 200	17 400	17 600	17 700	17 800	17 900
·05	K_cR_{cm} =	·4	·4	·4	·4	·4	·4

THE CHOICE OF TELEPHONES.

Coming now to the discussion of the most suitable telephone resistance for use with the above detectors, we shall have, as before, two cases to consider. The matter is somewhat complicated by the fact that the impedance of the telephones will vary very greatly with frequency.

If a constant input potential can be assumed, then the best telephone load will be that for which the impedance over the most important part of the audible range of frequencies is equal in magnitude to the apparent internal resistance of the detector under the given conditions of amplitude. This would indicate the use of very low resistance telephones for large signal amplitudes, and high resistance telephones for small signal amplitudes.

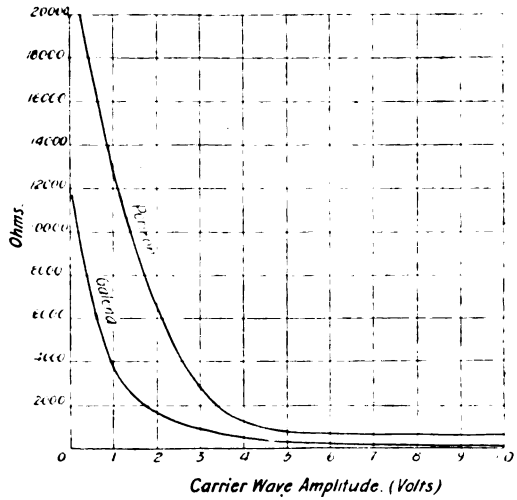

Fig. 29. *Values of R_{cm}, the apparent internal resistance to audio-frequency output, for varying H.F. input and constant external load of 1 000 ohms.*

It has already been pointed out, however, that under most practical conditions of direct crystal reception a more suitable basis of comparison would be the efficiency of transformation of high-frequency power into modulation-frequency power. This cannot be very satisfactorily discussed without reference to exact figures for the variation of telephone impedance with frequency, a matter on which information is scarce. To obtain some idea of actual conditions we will assume the following data :—

$$E = 1 \text{ volt.} \qquad \mu = 15\%.$$

It will further be assumed that at some given audio-frequency the impedance will be about four times the D.C. resistance, and that the phase angle will be 45°. The high-frequency power consumed in the detector can be calculated in the same way as for the continuous wave rectification already considered. The curves of Fig. 30 show P_n (the modulation-frequency power) and P_n/P_1 calculated for a galena detector under these conditions.

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It will be seen that whereas P_n reaches a very pronounced maximum for a very low value of R (about 100 ohms), P_n/P_1 reaches a maximum for a considerably higher value of R (about 450 ohms) this maximum being much less pronounced than the former. It seems probable that where a galena detector is used with moderately large signal amplitudes there is nothing to be gained by using telephones of very high resistance. It

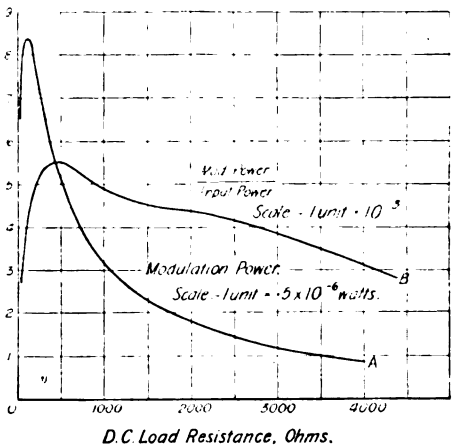

Fig. 30. *For one set of conditions ($E=1$V, $\mu=15$ per cent.) the output power and power efficiency have been worked out for galena.*

must be remembered, however, that if low resistance telephones are used, steps should be taken to reduce the damping imposed by the detector circuit on the aerial by some such means as those described in the article by the present writer on the subject of crystal reception in the *Wireless World* of July 23, 1924.

It will be seen from the above table that the telephone resistances appropriate to a perikon detector will be in all cases three or four times as large as those most suitable for galena.

For small signal amplitudes (about .25 volts or less), the maxima of P_n and P_n/P_1 will be associated with more nearly equal values of R, for reasons already given. For these smaller amplitudes it appears that high resistance telephones are likely to be more efficient than low resistance telephones.

It should be noted that under equally favourable load conditions galena should give a very much greater signal strength than perikon. In practice the superiority is less marked than the above discussion would indicate, but this is probably due to the fact that the usual conditions of operation will be less inefficient for perikon than for galena.

The above statements are admittedly no more than roughly approximate generalisations. The very variable character of the quantities involved will not permit of any greater exactitude.

10. Distortion in the Rectification of Modulated Currents.

Whether or no distortion is produced in the rectification of a modulated continuous wave, and the degree of such distortion, if any, will depend not only on the characteristic of the rectifier but also on the conditions under which it is used, more particularly the load conditions.

We have seen that an ordinary crystal detector with no modulation-frequency load will give a modulation-frequency current which is, to a high degree of approximation, a faithful reproduction of the modulation E.M.F. To this extent crystal reception can be regarded as distortionless. Again, if the modulation-frequency load be constant with respect to frequency, equation (8·13) shows that the modulation-frequency current will be a faithful reproduction of the modulation. In practice, however, the modulation-frequency load will be one which varies very greatly with frequency. Consider, for instance, the case in which a detector of internal resistance 500 ohms is used in conjunction with a pair of telephones of which the impedance varies from about 10 000 ohms to 40 000 ohms, with a phase angle of about 60°, over the important audible range of frequency. From equation (9·6) it will be seen that the efficiency factor $\Psi(\nu,\theta)$ will vary from ·024 to ·006 over the same range, i.e., a variation of 400 per cent. with frequency. This variation will undoubtedly cause a very pronounced distortion of the wave form of the modulation, but the effect that this distortion will produce on the ear is further complicated by the response characteristic of the telephones.

The whole subject is at present so little understood that no definite assertion can be made. All that can be said at present is that any distortion present in the telephone reception of modulated continuous waves

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with crystal rectification will be due almost entirely to the variation of the impedance and the acoustical efficiency of the telephones, and not to the crystal itself.

11. The Influence of Contact Conditions.

(*a*) *Galena.*

During the experimental work, rough comparisons of the efficiency of rectification were made with various metals as the contact wire or "cat-whisker." The impossibility of reproducing exactly equal conditions for the various cases makes it very difficult to draw a definite conclusion, but no very marked differences were observed. It appeared that differences attributable to a variation of the contact metal were considerably less than those which would arise from variation of the actual point of contact. The suitability of the metal is probably decided by other considerations, such as immunity from surface oxidation. For the measurements described a finely pointed silver wire was used.

An attempt was also made to investigate the effect of contact pressure, but, for the same reasons, no very definite conclusion could be reached. It seemed, however, that provided a finely pointed wire is used, the detector is not very sensitive to contact pressure. In practice a moderately firm pressure can be used without apparent loss of sensitivity and with a gain in stability.

(*b*) *Perikon.*

In this case, quite definite conclusions were obtained. It was found that a heavy contact gave a very much greater no-load sensitivity, with a constant input potential. An increase up to 500 per cent. was obtained by increasing the contact pressure. With a high resistance load, however, the effect went the opposite way, but to a much less extent, the sensitivity decreasing by an amount up to about 30 per cent. with increased contact pressure. These apparently contradictory results can be explained very simply in terms of the apparent rectified E.M.F. and the apparent internal resistance. The decrease of sensitivity with a high resistance load indicates that there is a decrease of the rectified E.M.F. with pressure; the increase of sensitivity at no-load indicates that this slight decrease in the rectified E.M.F. is more than compensated by a considerable decrease in apparent internal resistance.

In confirmation of this, it was found that the open circuit rectified E.M.F. was decreased by an amount up to about 30 per cent. by increase of contact pressure. An examination of the static characteristics corresponding to a light and a heavy pressure revealed the cause of these changes. It was found that the increase of contact pressure resulted in a considerable increase of conductivity in both directions. Under practical conditions of operation, this would have the effect, not only of decreasing the rectified E.M.F., but also of reducing very considerably the effective high-frequency resistance of the detector circuit. Both of these changes will result in a lower efficiency. These conclusions are confirmed in the practical application of this type of detector to the reception of telephony. It may be concluded that the holder for perikon crystals should be designed on comparatively massive lines, for the sake of rigidity, and should permit of very fine and smooth adjustment of the contact pressure.

12. The Variation of the Sensitivity with Wave-length.

All the measurements described were carried out at a constant wave-length of

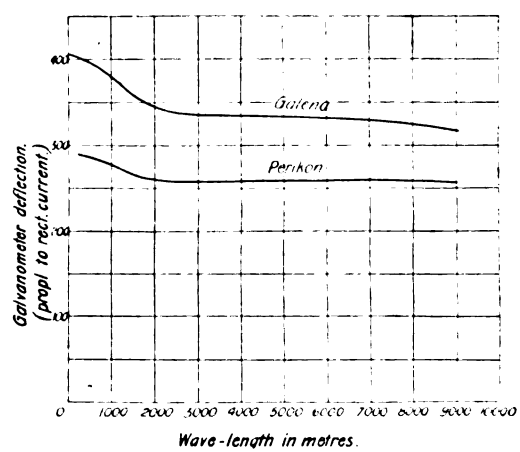

Fig. 31. *The effect of input wave-length on output is not very great.*

about 400 metres. The effect of variation of wave-length is exhibited in the curves of Fig. 31. It will be seen that in each case

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the sensitivity decreases slightly as the wave-length increases, but that the change is comparatively small.

13. Summary of Results with Simple Crystal Rectifiers.

(i) The apparent dynamic characteristic of a crystal detector may differ by as much as 80 per cent. or so from its static characteristic. The dynamic conductivities of the galena specimens tested appear to be higher, and those of perikon lower, than the static conductivities.

(ii) The important features of a crystal detector are:—

(*a*) The apparent rectified E.M.F. This appears to vary from about 25 per cent. to 80 per cent. of the signal amplitude with variation of D.C. load and amplitude for both types of detector examined. In general, it increases with the load.

(*b*) The apparent internal resistance. This varies very greatly with the signal amplitude and to a less extent with the load. Probable limits for large and small amplitudes are: For galena, 50-100 ohms to 10 000 ohms; for perikon, 300-500 ohms to 20 000 ohms. The apparent internal resistance increases very rapidly as the amplitude decreases from about ·3 volts.

(*c*) The effective high-frequency resistance of the complete detector circuit. For a constant signal amplitude this varies greatly with the D.C. load in series with the detector. At large amplitudes it will increase from a comparatively low value at no-load to a magnitude comparable with that of the D.C. load at higher load resistances. At infinite loads (*i.e.*, open circuit rectification) it will probably be very high, of the order of tens of thousands, being comparable with the reverse direction conductivity of the detector. For small signal amplitudes the high-frequency resistance will vary comparatively little with the D.C. load, and will be in general between 10 000 and 100 000 ohms.

(iii) For comparatively large signal amplitudes (greater than ·4 volts) a crystal detector of either type will give under ideal conditions a very faithful reproduction of telephony or other modulation. In practical crystal reception some distortion is present, but this is almost entirely due to the nature of the modulation-frequency load. The purity of the reproduction of modulation given by a rectifier is decided chiefly by the straightness of the rectification characteristic over the range of signal amplitude represented by the modulation.

(iv) The most efficient loads for use with a crystal detector will depend not only on the apparent internal resistance of the detector, but also on the input energy conditions. If we assume constant input *power*, the best load will be that giving the highest efficiency of transformation of high frequency into continuous or modulation-frequency power. Such loads will in general be of considerably higher impedance than those which would be appropriate to the detector if a constant input *potential* could be assumed.

(v) The apparent internal resistance of a crystal detector for the modulation-frequency components of the rectified current will vary considerably with the carrier wave amplitude, and to a less extent with the D.C. load. It will in all cases be comparable with and of the same order of magnitude as the no-load internal resistance of the detector for continuous current.

(vi) With either type of detector the rectified modulation-frequency E.M.F., with carrier wave amplitudes greater than about ·4 volt, will be from ·5 to 1 times the mean modulation percentage times the carrier wave E.M.F. acting in the detector circuit. For very small signal amplitudes the modulation-frequency E.M.F. produced in the detector circuit will be proportional to the square of the carrier wave E.M.F. acting in the detector circuit.

This concludes the application of the general theory of the rectification of small radio-frequency potential differences to typical crystal rectifiers. For the sake of completeness, we go on to consider one or two special cases in which the similar methods of analysis are useful.

It might be stated that the author has in preparation the extension of the general theory to include valve rectification, and has developed a method by means of which the quantitative behaviour of any small receiving valve can be predicted to a fairly high degree of accuracy from its static characteristics.

14. Crystal-Valve Combinations.

One very simple crystal-valve combination has already been mentioned and was

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illustrated in Fig. 22. It was shown that the application of a continuous wave E.M.F. $E \sin \omega t$ to the terminals of the detector would produce a change v_0 of potential across the condenser, v_0 being the solution of equation (6·2). In the general case v_0 will of course be a function of E, and it will be seen from the curves given among the experimental results that in the case of a galena or a perikon detector the function is such that its change of slope over a small variation of E is exceedingly small. Expressing v_0 in the form

$$v_0 = \chi(E) \quad .. \quad .. \quad (14{\cdot}1)$$

it follows that the variation of E due to the modulation m will result in a change of potential v_m of the modulation frequency and wave form superimposed on v_0, where

$$v_m = m\chi'(E) \quad .. \quad .. \quad (14{\cdot}2)$$

It is here assumed that the condenser will not introduce any appreciable time-lag in the potential changes, a condition which can be satisfactorily realised by making its capacity no larger than is necessary to provide a path for the high-frequency currents of low impedance compared with that of the crystal, i.e., about ·000 3μF for the broadcast range of wave-lengths. This modulation frequency change of grid potential will of course give rise to an exactly corresponding component of anode current in the usual way. The purity of the reproduction given by this method of rectification will clearly depend on the straightness of the function $\chi(E)$ over the range of variation m. It will be seen later that either of the ordinary types of crystal detector will probably be quite satisfactory in this respect.

Another very common crystal-valve combination is that illustrated in Fig. 32. It would appear at first sight that this arrangement would not be free from distortion on account of the use of a low frequency transformer. It can easily be shown that this is not necessarily the case. If $\dot{Z}_n$ be the operative impedance of the primary winding of the transformer at the frequency $n/2\pi$, then, from equation (8·11), using the abbreviations which have already been introduced,

$$\mathbf{I}_n = \frac{K_c \mathbf{M} R_{cm}}{R_{cm} + \dot{Z}_n} \quad .. \quad (14{\cdot}3)$$

The p.d. across the primary winding will therefore be

$$\mathbf{V}_n = \frac{\dot{Z}_n}{R_c + \dot{Z}_n} (K_c \mathbf{M}) R_{cm} \quad .. \quad (14{\cdot}4)$$

In nearly all practical cases $\dot{Z}_n$ will be so large compared with R_{cm} that $\dot{Z}_n/(\dot{Z}_n + R_{cm})$ will only differ very slightly from unity, i.e.,

$$\mathbf{V}_n = K_c \mathbf{M} R_{cm} \quad .. \quad .. \quad (14{\cdot}5)$$

to a close approximation. Putting this in scalar form,

$$v_n = R_{cm} K_c M \sin nt \quad .. \quad (14{\cdot}6)$$

If σ_n be the voltage step-up ratio of the transformer at the frequency $n/2\pi$, then the potential difference operating on the grid of the valve will be

$$\sigma_n v_n = R_{cm} P_n K_c M \sin nt \quad .. \quad (14{\cdot}7)$$

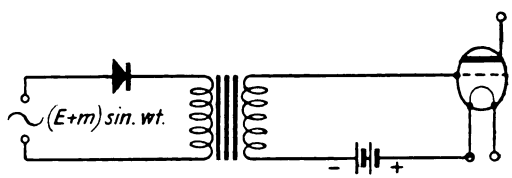

Fig. 32. *The most usual type of crystal-valve circuit.*

In this case, therefore, the purity of the reproduction will depend, not on the variation of the impedance of the transformer, which is the usual cause of transformer distortion in valve circuits, but on the constancy of the ratio of transformation. For a full account of this last factor the reader is referred to the series of articles by Mr. Dye on the subject of low-frequency transformers, commencing in the September (1924) number of E.W. & W.E. It can be said that in general the variation of σ_n with frequency is relatively unimportant as a cause of distortion, and can be made very small indeed by suitable design. With a good transformer, therefore, the above combination should be free from any appreciable distortion. It is, moreover, a very effective arrangement, since it provides a multiple of the rectified E.M.F. for the operation of the valve.

It might be mentioned that the writer has actually compared the two arrangements described above (the direct connection of the crystal to the grid and the transformer connection), by means of a change-over switch, a resistance-coupled amplifier being

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used to avoid subsequent distortion. It was found that the transformer gave a very marked increase of intensity without any apparent modification of the quality, this result being consistent with the above discussion.

It should be noted that a transformer intended for use with a crystal need not have so high a primary impedance as one intended for use with a valve, and can therefore be wound to a higher transformation ratio with advantage.

15. Heterodyne Reception.

In heterodyne reception the signal E.M.F., which we will express in the form

$$e_1 = E_1 \sin(\omega_1 t + \theta_1) \quad \ldots \quad (15{\cdot}1)$$

is combined with another E.M.F.,

$$e_2 = E_2 \sin(\omega_2 t + \theta_2) \quad \ldots \quad (15{\cdot}2)$$

before the process of rectification, the second E.M.F. being induced in the receiving circuit by any suitable means. The E.M.F. acting in the rectifying circuit will therefore be of the form

$$e = E_1 \sin(\omega_1 t + \theta_1) + E_2 \sin(\omega_2 t + \theta_2) \quad \ldots \quad (15{\cdot}3)$$

Let

$$\omega_1 = \omega + n \quad \ldots \quad (15{\cdot}4)$$

and

$$\omega_2 = \omega - n \quad \ldots \quad (15{\cdot}5)$$

i.e.,

$$n = \frac{\omega_1 - \omega_2}{2} \quad \ldots \quad (15{\cdot}6)$$

$$\omega = \frac{\omega_1 + \omega_2}{2} \quad \ldots \quad (15{\cdot}7)$$

Then

$$e = E_1 \sin[(\omega + n)t + \theta_1] + E_2 \sin[(\omega - n)t + \theta_2] \quad (15{\cdot}8)$$

$$= E_1 \sin\omega t \cos(nt + \theta_1) + E_1 \cos\omega t \sin(nt + \theta_1) + E_2 \sin\omega t \cos(nt - \theta_2) - E_2 \cos\omega t \sin(nt - \theta_2) \quad (15{\cdot}9)$$

i.e.,

$$e = [E_1 \cos(nt + \theta_1) + E_2 \cos(nt - \theta_2)] \sin\omega t + [E_1 \sin(nt + \theta_1) - E_2 \sin(nt - \theta_2)] \cos\omega t \quad (15{\cdot}10)$$

Now let

$$E_1 \cos(nt + \theta_1) + E_2 \cos(nt - \theta_2) = E \cos\alpha \quad (15{\cdot}11)$$

and

$$E_1 \sin(nt + \theta_1) - E_2 \sin(nt - \theta_2) = E \sin\alpha \quad (15{\cdot}12)$$

i.e.,

$$E^2 = (E_1^2 + E_2^2) + 2E_1E_2 \cos(2nt + \beta) \quad (15{\cdot}13)$$

where

$$\beta = \theta_1 - \theta_2 \quad \ldots \quad (15{\cdot}14)$$

The E.M.F. acting in the circuit can therefore be reduced to the simple form

$$e = E \sin(\omega t + \alpha) \quad \ldots \quad (15{\cdot}15)$$

where E has the value determined above, and where

$$\tan\alpha = \frac{E_1 \sin(nt + \theta_1) - E_2 \sin(nt - \theta_2)}{E_1 \cos(nt + \theta_1) + E_2 \cos(nt - \theta_2)} \quad (15{\cdot}16)$$

It will be seen that α is not a constant with respect to time. The nature and extent of its variation can be judged from the facts that if E_1 is small compared with E_2, which is frequently the case in practice, α approaches the limit $(nt - \theta_2)$, i.e.,

$$\omega t + \alpha = (\omega - n)t - \theta_2 \quad \ldots \quad (15{\cdot}17)$$

while if $E_1 = E_2$

$$\alpha = \frac{\theta_1 + \theta_2}{2} \quad \ldots \quad (15{\cdot}18)$$

In the general case the fact that α is not a constant can be regarded as equivalent either to a slow variation of the phase of the oscillation $E \sin(\omega t + \alpha)$ or as a periodic very small variation of the frequency. In any case it will have no appreciable effect on the magnitude of the continuous or low-frequency components of the rectified current.

To an E.M.F. of the form given in equation (12·15) the whole of the preceding analysis can be applied, with the following simple modification :—

The expression for the "no-load" continuous current given by the rectification of an E.M.F. $E \sin(\omega t + \alpha)$ by means of a rectifier having the characteristic $i = f(e)$ was stated in the form

$$i_0 = \frac{1}{T}\int_0^T f(E \sin \overline{\omega t + \alpha}).dt \quad (15{\cdot}19)$$

$$= F(E) \quad \ldots \quad (15{\cdot}20)$$

the graph of $F(E)$ being obtained by plotting i_0 against E. It would, of course, be equally simple to plot i_0 against E^2, giving

$$i_0 = F(E) = H(E^2) \quad \ldots \quad (15{\cdot}21)$$

It is the latter function, $H(E^2)$, and its various derivatives which are of importance in connection with heterodyne reception. From the form of the amplitude E in equation (15·13) it is clear that there will be, in addition to the continuous component i_0, a number

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of low frequency currents which can be represented by the general symbol i_m, i.e.,

$$i_0+i_m=H(E^2) \quad \ldots \quad \ldots \quad \ldots \quad (15{\cdot}22)$$

$$=H[(E_1^2+E_2^2)+2E_1E_2\cos(2nt+\beta)] \quad (15{\cdot}23)$$

$$=H(E_1^2+E_2^2)+$$
$$2E_1E_2\cos(2nt+\beta)\,H'(E_1^2+E_2^2)+$$
$$\frac{4E_1^2E_2^2}{2!}\cos^2(2nt+\beta)H''(E_1^2+E_2^2)+\ldots$$
$$+\frac{(2E_1E_2)^m}{m!}\cos^m(2nt+\beta)H^m(E_1^2+E_2^2)+\ldots \quad (15{\cdot}24)$$

where

$$H^m(x)=\frac{d^m}{dx^m}H(x) \quad \ldots \quad (15{\cdot}25)$$

Now $E_1^2E_2^2$ will in general be a very small quantity. Further, it will be seen from the curve of Fig. 33, which shows $H(E^2)$ plotted against E^2 for a typical crystal rectifier, that $H''(E_1^2+E_2^2)$ will also be relatively small, i.e., over the small range of variation represented by $2E_1^2E_2^2$ the $H(E^2)$ line is sensibly straight. The principal component of i_m will therefore be a current of frequency $2n/2\pi$, the amplitude of which is given by

$$i_{2n}=2E_1E_2H'(E_1^2+E_2^2)\cos(2nt+\beta) \quad (15{\cdot}26)$$

The case is thus seen to be very similar to that of the rectification of a modulated continuous wave, with the difference that whereas in the latter process the important factor is the slope of the $F(E)$ line, in the former it is the slope of the $H(E^2)$ line. The equations for the behaviour with respect to load will be similar to those applying to the modulated continuous wave, and need not be restated in detail.

It should be noted that if the $H(E^2)$ line is appreciably curved over the range of variation involved, the third and subsequent terms of equation (11·24) may become appreciable. This will result in the introduction of currents of frequencies $4n/2\pi$, $6n/2\pi$, etc. This will not matter in the case of morse reception, where purity of tone is unimportant, but it may have significance in the case of superheterodyne reception of telephony, and will be referred to again later.

It will be of interest to compare the amplitude of the audible-frequency current with the magnitude of the continuous current which would have been produced by the same rectifier under the action of the same signal but without heterodyne. The latter is given by

$$i_0=F(E) \quad \ldots \quad (15{\cdot}27)$$

The ratio is therefore

$$\frac{I_{2n}}{i_0}=\frac{E_1E_2H'(E_1^2+E_2^2)}{F(E)}$$

For the typical crystal rectifier illustrated in Fig. 15, and assuming the values

E_1=·1 volt
E_2=·5 volt

the actual value of this ratio is 19·7, which illustrates the great gain in reception sensitivity obtainable by heterodyning. The gain is particularly marked in the reception of very weak signals. Thus, in the above case, if E_1=·025 volt the ratio is about 80.

16. The Supersonic Heterodyne.

The principle and objects of superheterodyne reception are too well known to need description. As applied to the reception of continuous waves, the first process is that described in the preceding paragraph, with the difference that the beat frequency, instead of being in the audible range, is adjusted to some fairly low radio-frequency suitable for efficient amplification.

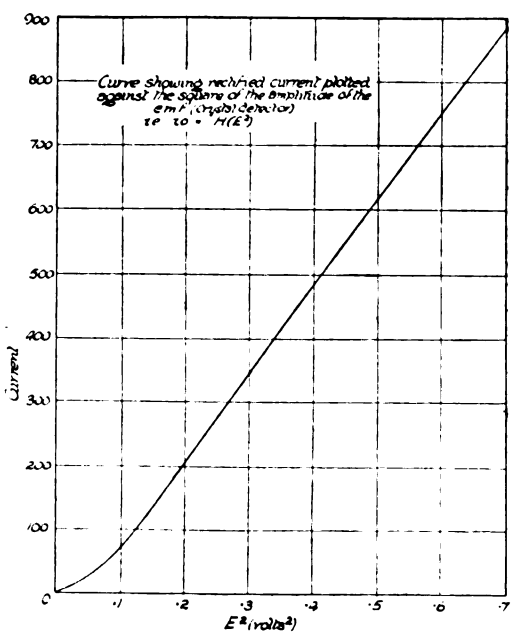

Fig. 33. *For heterodyne work, the connection between output current and the square of H.F. voltage is important.*

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A valuable feature of this method, and one which, at first sight, seems very remarkable, is that it can be applied to the reception of speech- or music-modulated continuous waves of very short wave-length without apparently modifying the wave shape of the modulation in any way. The reason for this can be made clear from the preceding analysis.

If $\omega_1/2\pi$ be the carrier wave frequency of the signal, and $\omega_2/2\pi$ that of the local heterodyne E.M.F., then it was shown that the predominant component of the rectified current would be one whose magnitude is proportional to the amplitude E_1 of the original signal and whose frequency is, say, $p/2\pi=(\omega_1-\omega_2)/2\pi$. In the case of valve rectification this will give rise to a grid potential of the same character, i.e., putting e for this rectified radio-frequency signal operating on the grid of the first intermediate-frequency amplifying valve, we have

$$e = kE_1\cos(pt+\beta) \quad .. \quad (16\cdot1)$$

The steps in the argument leading to this conclusion will not be affected in any way if the amplitude E, instead of being a constant, is of the form

$$E = E_c+m.. \quad .. \quad .. \quad (16\cdot2)$$

where E_c is the constant carrier wave amplitude and m an audible-frequency modulation of more or less complex wave form. Assuming therefore that the process of high-frequency amplification does not produce distortion, a matter which is outside the scope of the present discussion, the E.M.F. which is finally available for rectification will be of the form

$$e = k'E_1\cos(pt+\beta') \quad .. \quad (16\cdot3)$$

$$= k'(E_c+m)\cos(pt+\beta') .. \quad (16\cdot4)$$

The transformation of this by rectification into a current of modulation frequency and modulation wave form will be exactly as already shown in the preceding sections of the paper.

It was shown in paragraph 15 that any appreciable curvature of the $i_0=H(E^2)$ characteristics of the initial rectifier would result in the production of currents of frequencies which were multiples of the beat frequency. Even if such parasitic frequencies are produced, however, it does not follow that they will be present in the E.M.F. which is finally rectified. They can, in fact, be very effectively eliminated by the use of an intermediate amplifier having a selective characteristic. The superheterodyne method is thus capable of giving a high degree of purity of reproduction of the original modulation.

Wireless Engineering in American Universities.

Professor Charles L. Kinsloe, the head of the electrical engineering department at Pennsylvania State College, was interviewed recently in New York in order to obtain his views with regard to whether or no American Universities would institute a course of wireless engineering.

He stated that he did not think it was the purpose of the more important colleges to include wireless engineering in their curricula; the greater necessity is an absolute knowledge of the fundamental principles of the science of electrical engineering. Companies and manufacturers, he said, of the type who would employ such students on their completion of the course, recommend that specialisation should be avoided and that a general basic foundation should be concentrated upon.

The World's Highest Station.

What is claimed will be the highest wireless station in the world is being erected by the French Government in connection with the observatory on the summit of the Pie du Midi, at a height of approximately 9 430 feet above sea level.

Amateur Broadcasting in Switzerland.

The amateur transmitters of Switzerland are forbidden by their governmental authorities to employ a power of over fifty watts in their stations. Their wave-length regulations conform to the general boundaries enforced in other countries: amateurs must utilise a wave lying between 180 and 200 metres. Thus it is necessary that anyone working above or below the wave-length limits, or using a greater power than 50 watts, should obtain a special licence.

The various sections of the Swiss Radio Club are already planning to awake greater interest in the science of wireless telephony and telegraphy, and to encourage the erection of amateur stations in Switzerland.

An Australian Association.

According to news lately received from Sydney, the Institution of Radio Engineers of Australia has been formed to advance the interests of those engaged in wireless telegraphy and telephony, and to promote the science and practice of the profession throughout the Commonwealth.

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The Perfect Set.

Part VIII: Stability in H.F. Amplifiers. [R132

This instalment completes our treatment of H.F. Amplification, and we shall next consider some special circuits.

IN our last article we discussed generally the favourite couplings for H. F. amplification. It is now proposed to devote some attention to stability. As it happens, we are spared much of the explanation which would otherwise have been necessary, for the subject was treated admirably in our last issue by Mr. O. F. Brown, M.A., B.Sc., whose article was largely based on a special memorandum prepared by him for the Radio Research Board.

In this article, Mr. Brown devoted special attention to what we may call "compensating" methods. We, however, will first deal with "stabilising" methods. The distinction is that the former try to effect a radical cure, by compensating out the fundamental cause of the trouble—the Miller effect—while the latter are really palliatives, to avoid inconvenience by treating the symptoms only. One might justly compare them to the two methods of treating a bad complexion, by ointment or by blood medicine.

None the less the palliative methods are extremely useful, provided they are used intelligently. The great point to be remembered is that the trouble is due to regeneration which tends to cause some closed capacity-inductance circuit to oscillate. If we add resistance to this circuit we can kill this tendency, and, in the author's opinion, without loss of efficiency, for we *want* each circuit to have a small definite positive resistance. On the other hand, some of the methods which have been suggested aim at producing stability by lowering the effective amplification of the valves, which spoils the effectiveness of the set.

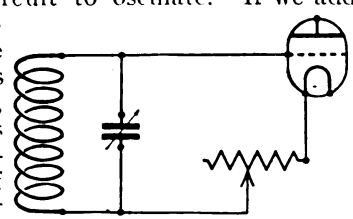

Fig. 1.

Two favourite methods fall into this category, and will therefore only be given as examples of what to avoid. The first is that of taking the grid leads to a potentiometer, and making them sufficiently positive to stop oscillation. One is usually told that this is effective because the resulting grid currents make the valve act as a comparatively low resistance across the input circuit, and so cause damping. This, in itself, is a legitimate method. But the trouble is that in doing it we are almost certainly spoiling the amplification. The method is most decidedly not one to be adopted.

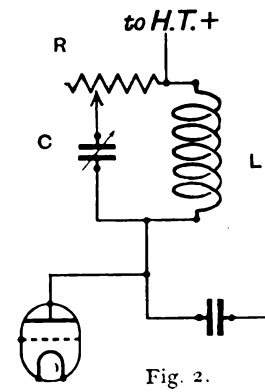

Fig. 2.

An even worse alternative is that in Fig. 1, of inserting a series resistance in the input lead. If this resistance is large enough to be effective, it is simply cutting down the proportion of the input voltage which gets to the valve. It thus cuts down the effective amplification. At the same time, as will be noticed, it offers no hindrance whatever to oscillations in the input circuit *A*, which it does not stabilise at all. It is merely quoted here as an awful example.

The limit offered in the last paragraph leads us to the solution. It is not the *valves* that want stabilising, but the *circuits*, especially those parts forming closed inductance-capacity loops. A valve cannot oscillate without oscillating circuits.*

The device shown in Fig. 2 is a practical embodiment of this idea. It consists simply of inserting, in the "tuned anode" circuit, an ohmic resistance. Note that the same

* Always true, though in some cases the closed circuit may contain only a foot or two of wire and the valve's own capacities.

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connection can be used if L is the primary of a transformer. Observe that R is not in the D.C. anode supply circuit, so that even if its value is high it in no way affects the steady anode voltage. It is simply a damper for oscillating currents within the closed circuit LC. Incidentally, besides being a stabiliser, it is to some extent a compensator. Calculation shows that it may have quite an appreciable effect in diminishing the Miller effect from the start as well as in helping to mitigate the results.

It might be thought that the waste of energy in R would lead to low amplification, but that is not the case. We are trying to cope with a set which has *superabundant* energy. Provided that no more resistance is inserted at R than is necessary to stop free oscillation, the *net* H.F. resistance of our circuit remains nearly zero. The author has at present in use a set with 2 or 3 stages of H.F. controlled in this way. Without the stabilisers, a fair amount of negative reaction is needed. With about 200 ohms of resistance in, considerable positive reaction is used, the final reaction control being entirely on the stabilisers. It is an especially useful point that this final control has only the faintest perceptible effect on the tuning. The resistances R are actually potentiometers of the usual 400-ohm type, one end being left disconnected. They are, of course, inserted on the battery side of the condenser.

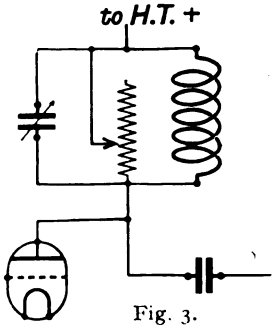

Fig. 3.

An equally good alternative depends on the fact already mentioned in this series, that a low series resistance in such a circuit as Fig. 2 is equivalent to a high resistance across it. This leads to a circuit such as Fig. 3, where R is a variable anode resistance of say 20 000 to 500 000 ohms. The choice between the two depends mainly on the following consideration: the circuit LC will be required to cover a certain range of wavelength. Now at the shortest waves covered—with condenser all out—the reactance of each side of the circuit will be at its maximum, and as the effect of R in Fig. 2 increases with its amount *compared with the reactance*, it will be least effective on the short end of the wave-range. But usually this is where it is most needed. In fact, as C is decreased, R must be considerably increased to keep stability. In the case of Fig. 3, however, the reverse is the case. R is more effective as it decreases compared with the reaction, hence it is more effective as C is decreased. It would appear, therefore, that Fig. 3 would need less adjustment than Fig. 2.

At the time when we built the set mentioned, there was not a really reliable variable anode resistance. Lately, however, we have temporarily connected some in, and although we have not yet had them in long enough to make definite statements, it certainly appears that Fig 3 is the better.

Of course, the action of this stabilising arrangement in no way depends on the LC circuit being in the anode lead. If transformers are used with the secondaries tuned, it may just as well be applied there.

Coming now to the compensation methods, the best known of these is almost certainly the "Neutrodyne." It is necessary, in considering this, to draw a clear distinction between the Neutrodyne principle in general, and the Neutrodyne set as a detailed design.

The main principle of the Neutrodyne is shown by Fig. 4. The trouble is, that when there is an alternating voltage at A, not only is this voltage impressed on L_1 as desired, but it also sends a current through C_1 L_2 (C_1 being the valve capacity), thus impressing a definite voltage on G, leading to regeneration. Now suppose we add the circuit L_3C_3, and by some means or other arrange to induce a voltage on L_3. Take, for example, the instant at which the voltage at A is sending a current through L_1 and C_1 as shown by the arrows I_1, I_2. Normally, I_2 would pass through L_2, but if the voltage in L_3 is at this instant such as to require a current I_2 going downwards, as shown by I'_2, then this can only be got by a current I_2 going up through C_3. No current from A can therefore flow through L_2, there will be no voltage at G due to that at A, and regeneration is avoided.

In practice, we apply the requisite voltage to L_3 by making it the transformer secondary, the voltage being induced in it from L_1. The amount of current is controlled by

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varying C_3. The most important point is to make sure that the voltage in L_3 is in the right direction; and it must be noted that this must be controlled by the actual direction (left-hand or right-hand) of the windings—*it cannot be got by simply reversing the connections.*

There is a real relation of principle between Neutrodyne and "Bridge" circuits, the idea in the latter being to turn the circuit into some sort of Wheatstone bridge which is balanced at all frequencies. These will not be treated here, as they were so admirably dealt with in the article already dealt with.

Unfortunately, the same trouble arises with both Bridge and Neutrodyne circuits, which prevents their being entirely perfect. This is the variability of the valve capacity itself; every change in frequency affects this somewhat, and it is therefore impossible to put up a fixed arrangement which will ensure complete stability at varying wavelengths. None the less, they are extremely valuable.

One last word: The peculiar arrangement

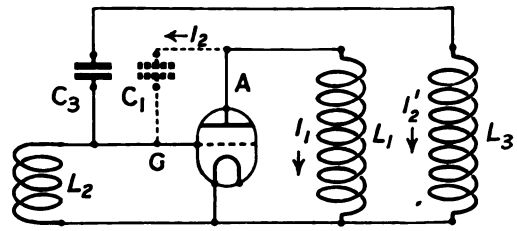

Fig. 4.

of tipped-up transformers adopted in the complete Neutrodyne set is introduced simply to avoid coupling from one transformer to another. *Verb. sap.:* it is useless to adopt elaborate circuits to avoid trouble due to valve capacities unless one takes every precaution, as a first step, to avoid casual coupling *outside* the valve.

Short-Path Discharge Rectifiers.

By Gerald R. Garratt (5CS). **[R336**

IN America, "short-path" rectifiers have received considerable attention, and much time and money has been spent in research work in connection with them; but in this country they have received little attention, and they are certainly not in common use as is the case in America, although the "S" tube of the Amrad Co. is available here. The theory underlying the operation of these rectifiers depends on the "mean free path" of an electron in a gas. It has been discovered that it is possible to design and locate two electrodes close together in gas at certain pressures in such a way that almost perfect insulation exists between them, except under certain conditions dependent on a magnetic field, while, if the electrodes are further apart, there is the usual gaseous conduction.

The separation of the electrodes, which usually take the form of concentric cylinders, is of the order of the mean free path of an electron in the particular gas in which the electrodes are located.

This mean free path may be defined as the distance an electron may travel in any gas, at a given pressure, without colliding with a molecule gas. The value of the mean free path is obtained by multiplying the mean free path of a molecule of the gas by $4\sqrt{2}$. The mean free paths of a molecule of oxygen, hydrogen and nitrogen are given in the following table, which is taken from Kaye & Laby's *Physical and Chemical Constants*, and it should be noted that the mean free path varies inversely as the pressure of the gas. The values below are at normal pressure—760 mm.

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Oxygen	.. 9.95×10^{-6} cm.
Nitrogen	.. 9.44×10^{-6} cm.
Hydrogen	.. 18.3×10^{-6} cm.

From these values the mean free path of an electron at any gas pressure may be calculated. For instance, at a pressure of .2 mm. of mercury the mean free path of an electron in hydrogen is :—

$$18.3 \times 10^{-6} \times 4\sqrt{2} \times \frac{760}{.2} = .39 \text{ cm.}$$

of the electrons leaving the cuter cylinder, and this increase is sufficient to cause a large number of collisions between the electrons and the molecules of the gas, with the result that ionisation and gaseous conduction at once commence ; while the path of the electrons leaving the inner cylinder seems either to remain unchanged, or, as is more probable, the path is actually shortened and hence ionisation and gaseous conduction are not set up.

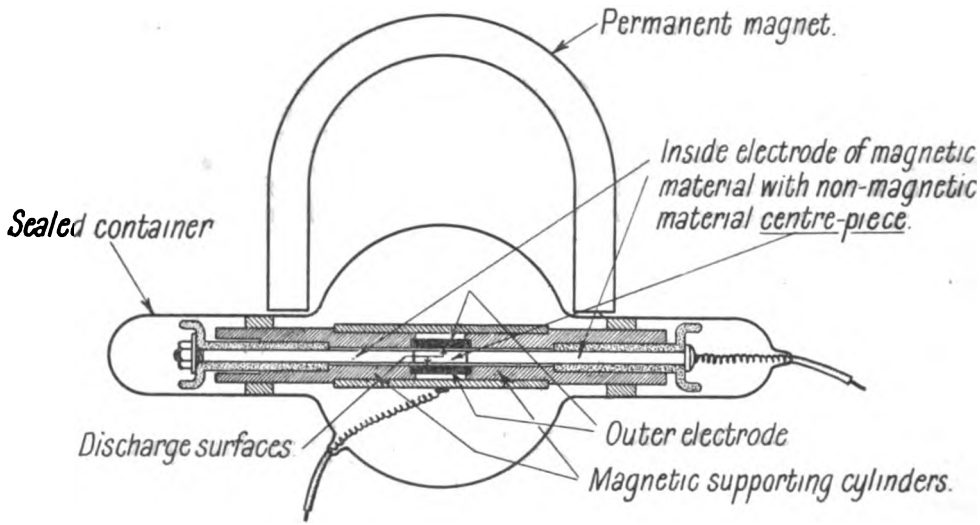

Fig. 1.

The actual spacing of the electrodes is not critical within certain fairly small limits, but if the spacing is increased too much ionisation will at once commence with the result that the insulation breaks down.

If however a constant magnetic field is suitably impressed upon the space separating the two electrodes, it is found that there is little or no insulation in one direction, while if the E.M.F. is applied in the reverse direction it is found that almost perfect insulation still exists.

The exact theory of this rectification is not at present fully understood, but it is believed to be due to a change in the length of the mean free path of an electron under the influence of the magnetic field.

The magnetic field, in some way, seems to cause an increase in the length of the path

From this it might be thought that the rectification would improve with an increase in the strength of the magnetic field, but for some reason this is not the case. When no magnetic field at all is present, almost perfect insulation exists up to potentials of the order of 10 000 to 15 000 volts, but when a magnetic field is impressed upon the gap the device is found to rectify provided that the strength of the magnetic field is between certain limits, which although not critical to any large extent depends on the actual design of the gap. If the magnetic field is too weak the gap will not conduct in either direction, and if it is too strong the gap conducts readily in both directions.

The conductivity of a gas at any moment can be said to depend on the number of ions present, but although there are always a few stray positive ions present, their

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number is too small to have any appreciable effect on the conductivity provided that their number is not increased by collision.

If the electrons given off from one electrode have normally only a short distance to go before reaching the other electrode, they will collide with only a very few atoms of the gas, and the number of positive ions produced to bombard the cathode and liberate electrons for the initiation of the gaseous discharge will be too small for practical consideration.

Fig. 1 shows a diagram of the rectifier as described in a patent specification by the American Radio and Research Corporation.

As may be seen from Fig. 1, it consists of two concentric electrodes of some non-magnetic material such as molybdenum. The electrodes are subjected to a potential difference, and when the tube is in an operating condition, current will be conducted from the outer to the inner electrode across the gap The electrodes are sufficiently close to prevent conduction in both directions even when subjected to very high potentials. The magnetic field, which is applied so that the lines of force are almost entirely parallel to the axis, causes conduction in one direction and insulation in the other. The magnetic field is set up by a permanent magnet external to the sealed container, but co-operating with the permanent magnet are two cylinders of magnetic material which serve to localise the magnetic field and which also serve to support the outer electrode.

In order to allow the heat generated in the gap to escape, the outer electrode and the connecting sleeve are perforated. The connecting sleeve itself is made of non-magnetic material, and serves only to support the magnetic cylinders.

The inner electrode consists of a small rod of non-magnetic material, which is fastened at both ends to magnetic rods of similar diameter which serve to support it in position. The rod is fastened at its ends to the magnetic cylinders but is insulated from them by glass or other insulating material.

The author regrets that, at the moment, only a small amount of practical data is available but it may be stated that a tube constructed as described above with a radial spacing of .085 inches filled with hydrogen at a pressure of .233 mm. of mercury will rectify with a magnetic field of from 112 to 150 gauss.

A rectifier of this description possesses many advantages over the usual type of valve rectifier which uses an incandescent filament or over the chemical "stew" which is a terrible trouble and a beastly mess!

1. Its life is not dependent upon any one element and hence the life of the tube is determined chiefly by its treatment and with careful use it will last several thousand hours.

2. It will rectify high voltages without the supply of energy to it in the form of filament current, etc.

3. It is extremely simple to use.

4. Owing to its special construction it is able to withstand short periods of excessive overloads.

(Overload is liable to cause heating with the consequent liberation of gases.)

5. It has comparatively low internal losses and the voltage drop across it is not excessive.

In conclusion, the author does not wish to imply that this short article is intended to be a complete treatise on discharge rectifiers, but it was written in the hope that amateurs may be encouraged to experiment in this direction as there is still much to be discovered in connection with them and there is probably a very large future for such tubes for such uses as the rectification of high voltage A.C. for transmission purposes for which service they are admirably suitable.

It should be noted that the "S" tube (see E. W. & W. E., December, 1924), while operating on the short path principle, does not utilise a magnetic field, the unilateral conductivity being achieved in another way.

VALVES FOR SALE.

Do any of our readers want 50-watt. Mullard transmitting valves?

An experimenter, living in London, has been forced to give up the work, and has for disposal two, stated to be new and unused.

We shall be pleased to forward any offers.

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Radio 2OA. An Amateur Station.

By E. A. Anson. **[R612**

THERE appear to be very few data available to anyone about to carry out C.W. transmission tests on low power. Diagrams there are in profusion, but actual results obtained with a given power, aerial and circuit are almost non-existent in the various papers devoted to wireless. Each experimenter has to do quite an amount of spade work, and personally

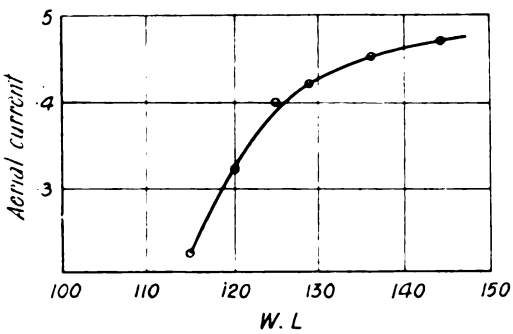

Fig. 1. *Aerial current plotted against wave-length.*

I felt quite cut off from reliable information on what to expect. This article is an attempt to give results with one of the most used circuits, and it is hoped it will be useful to those who are just taking up low power transmission on the amateur wave-lengths.

The locality of these tests is on the Firth of Forth, the site being open and flat, with no masses of houses within half a mile. Spray from the sea breaks over the room on rough days, and there are no trees near.

Wave-length tests were carried out first with an R valve (180 volts H.T. from dry cells), the aerial transmitting coil being a Burndept low-wave receiving coil, the aerial a single 7/22 wire 35 feet high and 100 feet long. The earth was a water pipe. Under these conditions an aerial current of ·05 amp was obtained. When an LS5 valve was substituted this was increased to ·18 amp.

A counterpoise—a 10-foot high duplicate of the aerial—was then substituted for the water pipe, which, using an LS5 valve, increased the radiation to ·28 amp. The circuit was a standard reversed feed back, and the actual circuit, aerial and counterpoise were not altered subsequently, an anode tap being the only addition.

A few remarks about the anode tap may be of use to others. It consisted of a 3s. 6d. broadcast variometer, and except for a tendency to melt under the influence of H.F. currents, it worked well. Of course a better-class variometer would have been more suitable. The importance of the anode tap cannot be emphasised too strongly, since in this case a half-turn of the variometer reduced the aerial current from ·8 to ·1 amp.

At this period transmission took place at the bottom of the garden in an outhouse amid a mass of wires and dry cells; reception, on the other hand, took place in the house on another aerial, necessitating a 50-yard walk

L.T. Volts.	H.T. Volts.	Milliamps with T15
12	388	18
14	474	27
16	550	35

Fig. 2. *Showing average output of Mackie generators.*

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carrying the one and only filament accumulator! Change over switching was apt to be slow—taking five minutes with luck. However, 5JX was very patient.

Having obtained sufficient data, a wave of 125 metres was selected as a result of the curve in Fig. 1 (probably quite wrongly), and a Mackie generator was obtained as advertised in all the wireless papers. Fig. 2 is a table showing what may be expected from these generators.

The L.T. current did not vary much, and at 16 volts was 8 amps, fed from self-starter accumulators. Although this generator ran warm no serious overheating was noticed. The revs. at 16 volts on H.T. load were 2 300 per minute. In order to raise the note of the hum as high as possible a 10-ohm resistance was inserted in series with the field shunt coils, and the revs. rose to 3 200, giving a commutator hum of 1 000 p.p.s. I do not know the size of the mica condenser supplied across the H.T. terminals, but it must be about 2μF, and the commutator ripple is very small even without a filter coil. (The makers informed me that the full output of 600 volts 80mA would be obtained with an L.T. input of 19 volts 10 amps, but that serious overheating would result if used for any but very short runs).

The transmitter circuit at present in use is shown in Fig. 3. Battery grid bias is used in place of the more usual grid-leak, because it is not only very much cheaper, but gives excellent results. A bias of 4½ volts negative on the grid appeared to be correct. Steadiness of wave, even in a gale, was much improved by earthing the filament negative. (Do not mix this with the counterpoise, which is well insulated from earth.)

An H.F. current of ·25 amp flows from L.T. negative to earth, and the aerial current increases by this amount. All combinations of counterpoise and earths proved unsatisfactory except in this manner. Incidentally, the earthing of L.T. negative removed all capacity effects when adjusting in the vicinity of the helix.

The grid coil is not rotatable, but has been adjusted to give maximum results on 125 metres without a tuning condenser. For high waves a ·000 25 variable air condenser is required.

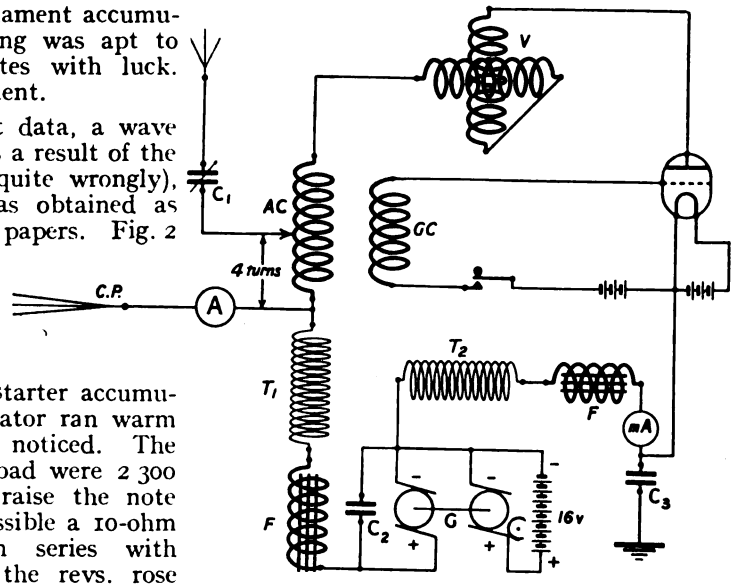

Fig. 3. *The transmitter circuit.*

All my variable condensers on the transmitter are good quality receiving condensers and they seem to function very well. The 500-turn H.F. chokes—Igranic coils—on the H.T. increased the aerial current by ·1 amp. The filaments are lit from my 6-volt car battery, leads being led to the garage for this purpose. Fig. 1 gives aerial current

10 in. Octagonal Helix.
¼ in. Copper Strip spaced ¾ in.
Bottom turn to counterpoise.

Aerial tap from Bottom.	Series Condenser .001 5 max. Ex-WD.	W.-L.
1 turn	12°	115
2 turns	20°	120
3 ,,	22°	122
4 ,,	30°	125
5 ,,	40°	129
6 ,,	41°	132
7 ,,	48°	136
8 ,,	52°	137
9 ,,	59°	140
10 ,,	62°	144

Fig. 4. *Coil and condenser settings for various wave-lengths.*

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against wave-length at a constant input. Fig. 4 gives coil and condenser settings for

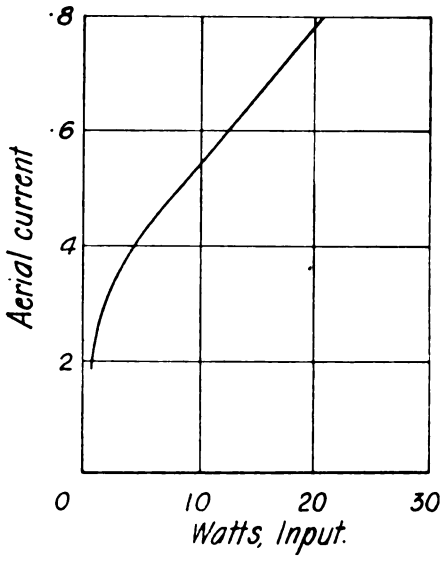

Fig. 5. *Aerial current against watts input.*

various wave-lengths, and may help those feeling their way to radiation. Fig. 5 gives aerial current plotted against watts input to the valve. I do not suppose for a moment that any of these curves are what they ought to be; they are what have resulted from taking ordinary care, and using good instruments.

A switching refinement has been installed lately. It consists of a Lucas Aero dynamo cut-out, connected as in Fig. 6. When the generator is switched on and is "revving" up, this cut-out operates as the starting load lessens and the valve filaments light. On switching off the generator this cut-out turns off the filaments. Two T15 valves are used in parallel at a filament voltage of 5·4. (One T15 will give the same results at 5·8 volts, but the life is shorter.)

The receiver consists of one H.F. detector, and—at will—one L.F. stage. R valves are used, and C.W. reception is possible down to 35 metres. The aerial coil is aperiodic, and untuned for all waves below 150 metres. A Burndept concert coil No. 4 is used, but any coil above this size will work, provided the long-wave stations do not come in. The tuned anode is the only tuned circuit. Although H.F. amplification is almost nil on low waves, the H.F. circuit is capable of extremely fine tuning, and for this reason alone is worth its filament current. The reaction is in the anode coil.

This is by no means a millionaire station, and, like 5KO, radiation and efficiency

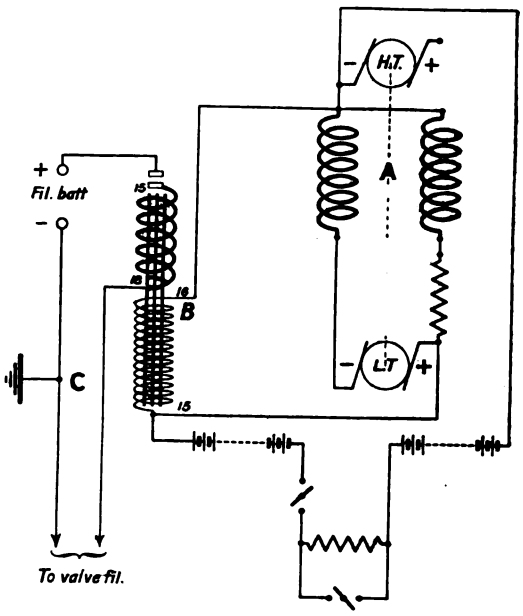

Fig. 6. *Showing the connections of the generator cut-out.*

have been the results of much thought and experimenting. DX results are no more than the average low-power amateur station. France, Sweden, Norway, all the British Isles, and—thanks to 2OD—C1AR have been received.

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Parasitic Losses in Inductance Coils at Radio-Frequencies.

By Raymond M. Wilmotte, B.A. **[R382·1**

Suggestions on the really important matters in low-loss coil design.

THE losses in inductance coils at radio-frequencies can be divided into two classes; first the loss in the wire of the coil itself, and second the losses in the surrounding medium. It is the latter that I term parasitic losses. They include losses produced by eddy currents in any neighbouring metallic object, such as screws, terminals, etc., and the losses in the surrounding dielectric.

1.—Loss due to surrounding Metallic Objects.

We shall first consider the losses in the surrounding metallic objects. Imagine a closed circuit of resistance R and inductance L, through which an alternating flux ϕ is passing, so as to thread through the circuit once only. The E.M.F. induced in the circuit is then

$$\frac{\phi}{\sqrt{2}}\omega.10^{-8} \text{ volts}$$

where the frequency is $\omega/2\pi$.

The power loss is, therefore,

$$\frac{R\phi^2\omega^2.10^{-16}}{2(R^2+L^2\omega^2)} \text{ watts.}$$

If L is small this becomes

$$\frac{\phi^2\omega^2}{2R}.10^{-16} \text{ watts.}$$

Thus we see that the loss is proportional to the square of the frequency and inversely proportional to the resistance.

A metallic object, placed near a coil in which alternating current flows, is subjected to an alternating magnetic field. The object can be considered made up of a large number of closed circuits similar to the one just considered. At low frequencies, when $L\omega$ is small, the power loss in the object will be proportional to the square of the frequency, but at high frequencies $L\omega$ may not be small compared to R; the loss will vary with the frequency, but not as quickly as its square.

At all frequencies and for all sizes of objects, the loss will be greater the lower the specific resistance of the material. Thus, a copper screw will produce a greater loss than a brass one. The case of magnetic materials is different, as the value of the flux passing through them is greatly increased; an iron screw will produce a greater loss than a brass one, although the specific resistance of brass is less than that of iron.

The loss is, of course, dependent on the position of the metallic object relatively to the coil, since it is a function of the magnetic field at the position considered. The calculation of the magnetic field produced by a straight uniformly-wound coil is extremely laborious. It is necessary to differentiate the usual formulæ for the mutual inductance between a coil and a circle. The results obtained are complex formulæ involving complete elliptic integrals of all three kinds. For the present purpose, I have roughly calculated the axial and radial components of the magnetic field of a single layer coil having its length equal to its diameter (Fig. 1). The curves in Fig. 2 represent the square of the magnetic force at various radial distances along a diameter AB passing through the centre of the coil (the dotted curve) and for various positions along the axis CD of the coil. The lines MN and $M'N'$ represent the limits of the coil, and the letters Q, A, B, C, D, in Fig. 2, represent the same points as in Fig. 1.

It will be noticed that the dotted curve goes to infinity at the surface of the coil. This assumes that the wire is infinitely thin. In practice the finite size of the wire and the spacing of the turns alters slightly the magnetic field at points in close proximity

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to the wires themselves. Apart from this small difference the field is identical with that shown in Fig. 2, which is worked out for the ideal case of a uniform current sheet.

The curves show how quickly the magnetic field decreases just outside the coil.

Since the loss varies as the square of the

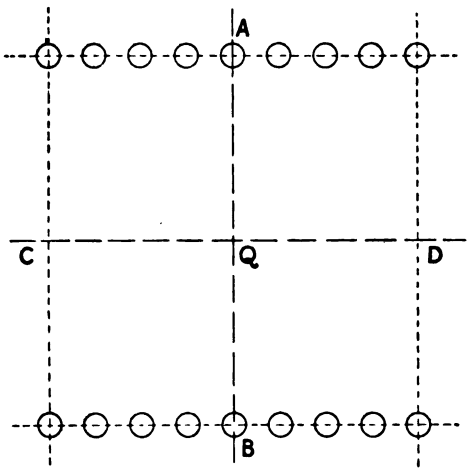

Fig. 1.

flux, it will be seen that the loss produced in a metallic object outside the coil will be very much less than if the object were placed anywhere within the coil. Thus the loss produced by placing a small metallic object in the centre of the coil would be about 10 times the loss in the same object placed on the axis at a distance equal to a quarter the diameter from the end of the coil.

To gain an idea of the magnitude of the quantities involved, a low resistance coil of 20 turns of No. 16 S.W.G. copper wire, having both its diameter and its length equal to 9 cms., was made. The effective resistance of the coil at a frequency of 1 500 kilocycles was about 0·6 ohm, and its self-inductance about 25 microhenries. By inserting in the centre of the coil a copper tube of 1 cm. side, the effective resistance was increased by 0·10 ohm, that is about 15 per cent.

The resistance of the coil was particularly low, but the intensity of the field was small owing to the comparatively large size for the number of turns used—since, for a given shape of coil, the intensity of the field is inversely proportional to the linear dimensions of the coil.

When a circuit containing a coil is tuned and a metallic object brought near the coil, the current decreases considerably. This is due primarily to the reduction of the inductance of the coil and but little to the increase of the resistance. The object usually affects the reactance of the circuit far more than its resistance. To obtain a true comparison of the effect on the resistance of the circuit, the latter must be retuned.

It will have been seen from the foregoing that, if care is taken to place all screws, terminals, etc., in suitable positions relative to the coil, their effect on the effective resistance of the coil will be very small and should not be greater than 1 per cent. or 2 per cent. of the total resistance, even at very high frequencies of the order of 2 000 kilocycles or thereabouts.

2.—Loss due to the Dielectric.

I have laid much stress on the effect of small metallic objects. This is not because the loss due to their presence is large, but because there exists a considerable variety of ideas on the magnitude of the loss produced by them. The effect of the dielectric is of greater importance. Unfortunately it is impossible to make coils commercially with only air as dielectric, and when a solid support is necessary it must be placed in contact with the wire, where the gradient of the electrostatic field is greatest.

A coil can be replaced by an equivalent circuit (Fig. 3) containing a resistance R in series with a self-inductance L, the two being in parallel with a capacity C in series with a resistance r. C is the effective self-capacity of the coil and L the effective self-inductance found by the ordinary methods. The losses are represented by the resistances R and r. R represents the loss in the metallic portion of the wire, as well as that due to eddy currents in the surrounding metallic objects, while r represents the dielectric loss, that is the loss due to the electrostatic field alone.

If P is the average power factor of the dielectric, we have $P = rC\omega$ .. .. (1)

It can be shown (see appendix) that the circuit shown in Fig. 3 is equivalent to a pure resistance R_0 in series with a pure self-inductance L_0, where

$$R_0 = \frac{R + rC^2\omega^2(L^2\omega^2 + R^2 + Rr)}{(1 - LC\omega^2)^2 + C^2\omega^2(R + r)^2} \quad .. \quad (2)$$

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and

$$L_0 = \frac{L(1-LC\omega^2)-C(R^2-r^2LC\omega^2)}{(1-LC\omega^2)^2+C^2\omega^2(R+r)^2}$$

We are only concerned here with R. When C is small and the frequency does not approach the natural frequency of the coil, we can write

$$R_0 = R(1+2LC\omega^2)+PL^2C\omega^3 \quad .. \quad (3)$$

in which we have eliminated r by means of equation (1). Thus if the worst material used in a coil has a power factor P, the increase in the effective resistance due to the dielectric cannot be greater than $PL^2C\omega^3$.

In a practical case, taking the following values :—

$$L\omega = 1\,000 \text{ ohms}$$
$$\frac{1}{C\omega} = 2 \times 10^4 \text{ ohms}$$
$$P = 0.02$$

we have

$$PL^2C\omega^3 = 1 \text{ ohm.}$$

It should be noticed that for a given shape of coil the value of C depends on the dielectric constant of the dielectric used. If C_0 is the self-capacity of the coil with air as the only dielectric and K is the average dielectric constant of the materials used the second term in equation (3) becomes :—

$$PKL^2C_0\omega^3 \text{ (approximately).}$$

For coils or panels then, the true criterion for a dielectric is not the power factor P but the product PK of the power factor and the dielectric constant. This fact does not seem to have been sufficiently realised, for in the little available data of losses in dielectrics at radio-frequencies, I have never seen this product mentioned.*

One more point is to be noticed ; that is that the equivalent series resistance due to the dielectric increases rapidly with frequency, namely as the cube, if the power factor is constant.

It has been assumed that the actual resistivity of dielectrics used is sufficiently high to ensure that the eddy current losses produced in them by the magnetic field are negligibly small. This may not always be the case, and it is possible that in very poor dielectrics, such as celluloid, this form of loss occurs. These dielectrics should, of course, never be used in conjunction with apparatus for radio-frequencies.

* See end of article.

In coils two forms of dielectrics are used : one must have suitable mechanical properties, and is used to support the wires in position ; the second is used as an insulating covering direct on the wire. This may be silk, cotton, enamel, etc. There should be the minimum quantity of the former necessary for a solid construction, while the latter should be dispensed with wherever possible. It is the latter, since it is placed where the potential gradient is greatest, which generally produces most of the dielectric loss in the coil.

Let us consider now the various insulating materials available. The data relating to dielectric loss at radio-frequencies are far from abundant. Furthermore, the values given must be very carefully used. It is not possible to see from colour and general appearance, even after considerable experience, whether one given example of material has the same properties as another. Considerable variations occur between similar materials sold by various manufacturers—ebonite is particularly at fault in this respect. Some samples may be extremely good, while others are so bad that one wonders whether it is really meant to be insulating material or merely high resistance. Owing to the high cost of the principal material,

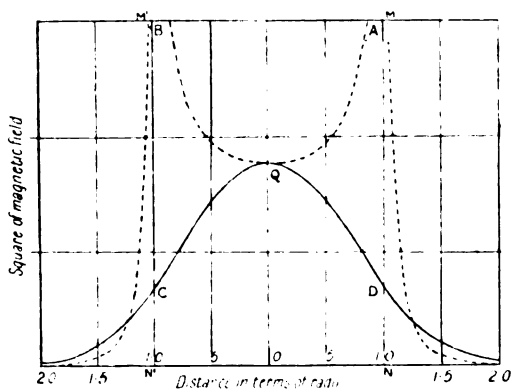

Fig. 2.

rubber, most manufacturers load their ebonite with some inorganic compounds. Ebonite thus loaded loses many of its exceedingly good qualities for radio work. Some manufacturers have also the habit of improving the appearance of their products by imparting on it a high surface polish, which is hardly suitable since this polished

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surface is usually very appreciably conductive.*

In the March number of the E.W. & W.E. (page 325) a list is given of the power factors of various materials taken from papers of R. V. Guthrie and of Preston and Hall. Unfortunately the dielectric constant is not stated, and a true comparison of the relative merits of the materials for coils and panels cannot be made. There are a few other sources of data. In this respect special mention should be made of the excellent papers of G. E. Bairsto (†), E. Schott (‡), and J. H. Dellinger and J. L. Preston (§).

G. E. Bairsto measured the power factor of a number of materials over a very large range of frequency. The materials tested were blotting paper, crown glass, vulcanised indiarubber, guttapercha, marble and slate; the frequency ranging from 1 to 3 000 kilocycles per second. Bairsto carried out this work just before the war, and the apparatus then available did not allow a high degree of accuracy. He obtained definite maxima near 600 kilocycles for all the materials he tested with the exception of marble and slate. It should be noticed that his values for marble show that this material is quite good, if the frequency is high enough, as the

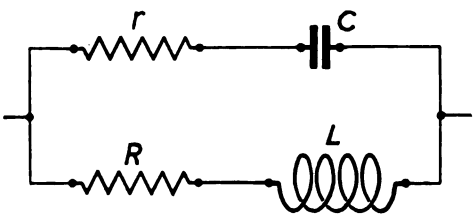

Fig. 3.

power factor decreases fairly rapidly with increasing frequency.

E. Schott, with more accurate apparatus, found the power factor of a large number of glasses of different composition and compared them with mica, ebonite, presspahn and amber. He also studied the effect of temperature in a range from —70°C. to 450°C., showing a rapid increase in the dielectric loss of glass above 100°C. or thereabout. His paper shows that he took considerable care over the measurements and his figures should be reliable. It should be noticed that, though he worked over a range of frequency from 200 to 1 000 kilocycles, he failed to obtain the maxima which G. E. Bairsto found.

We now come to the excellent paper of J. H. Dellinger and J. L. Preston. They investigated the properties of moulded and laminated phenolic insulating materials and compared them with those of ebonite and vulcanised fibre. In their paper of 125 pages they give the results of measurement of the power factor and dielectric constant over a range of frequency from about 100 to 500 kilocycles, depending on the sample. The insulating resistance, as well as the mechanical properties, effect of temperature, moisture, machining qualities, thermal expansivity, and the action of various chemical reagents were also investigated. It is not possible to give a *résumé* of their results.

Another paper on dielectric losses at radio-frequencies is one by W. Steinhaus* who investigated resin and waxes and the effect of temperature on them. It shows how remarkably small the losses in good waxes may be, the power factor being of the order of 0·002.

We have now to consider the effect of the insulation wound direct on the wire. It is not difficult to understand why no values have been published of the power factor of silk and cotton. The results would hardly be reliable if the usual methods of measurement were used.

In order to compare them, I made a small single layer coil of square section having approximately 7·5 cms. side. There were 30 turns with 1·5 mm. pitch, so that by using No. 22 S.W.G. wire, the turns were far from being in contact. Three types of insulation were used: double cotton, double silk and enamel. The effective resistance of the coil was measured by the variation of resistance method at a frequency of 1 000 kilocycles. The coil was then left in water for half an hour, wiped so that it just felt damp, and the resistance again measured; it was next dried by placing on a radiator for a quarter of an hour and further dried, if necessary, by placing in an oven. The results, which are considered reliable to within 0·02 ohm, are given in the table in the next page.

* It is to be noted that Mr. Wilmotte apparently intends these remarks to apply to *bad* ebonite. As will be seen further on, *good* ebonite remains, in spite of these disadvantages, still the best "building" insulator.—Ed. E.W. & W.E.

†. *Roy. Soc. Proc., A.*, Vol. 96, page 363, 1920.

‡. *Jahrb. d. Draht. Tele.*, Vol. 18, page 82, 1921.

§. *Tech. Papers of the Bureau of Standards*, No. 216, Vol. 16, page 501, 1922.

*. *Jahrb. d. Draht. Tele.*, Vol. 18, page 29, 1921.

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From these results it is seen that no difference can be detected between bare wire and silk-covered wire within the limits of accuracy of measurement. The effect of moisture is the same on bare wire as it is on enamel, due presumably to a thin film of moisture forming on the wires. The effect of moisture is more apparent on the silk insulation, but this is easily removed; while with cotton, the first measurement immediately after dipping in water shows that the resistance has increased 2½ times. Most of this disappears, however, on first drying over a steam radiator, but even on a second drying in an oven, the resistance of the coil does not quite return to its original value.

The case considered is not a very drastic one from the point of the dielectric, for the self-capacity of the coil is small, it being a single layer coil, having the turns between which there is a big difference of potential far apart.

Unfortunately, I have not the time at present to consider other cases, but it would undoubtedly be of much value should tests similar to the one given here be carried out for various shapes of coils.

3.—Conclusion.

It is evidently too much to ask the mathematician at present for a solution of the problem of the parasitic losses in coils, with odd shaped metallic objects and insulation of varying qualities. The problem is best attacked by direct measurement.

We have seen that, except for high grade coils having very low decrements, the effect of screws, terminals, etc., is very small, if care is taken in placing them where the magnetic field is small.

The problem of the dielectric is more complicated, as it must necessarily be placed where the potential gradient is greatest. We saw that, for a given power factor, the resistance due to the dielectric increased as the cube of the frequency and as the self-capacity of the coil. The latter should therefore be kept small. This is usually done by winding the wire so that there is no large difference of potential between adjacent turns. That this has considerable effect on the self-capacity is well shown by the fact that, in a set of coils for receiving sets, the smaller coils usually have a larger self-capacity than the larger ones. This is because in the small coils the first and last turns are much closer together than in the bigger ones. The size of the wire is also of considerable importance, for the potential gradient at the surface of the wire increases as the diameter of the wire diminishes, thus increasing the dielectric loss.*

Effective Resistance of Coil.

Insulation.	Effective resistance.	D.C. resistance.
	ohms.	ohms.
Bare	1·58	0·245
,, wet	1·68	
,, first drying ..	1·58	
D.S.C.	1·58	0·245
,, wet	2·09	
,, first drying ..	1·58	
Enamel	1·61	0·245
,, wet	1·71	
,, first drying	1·61	
D.C.C.	1·64	0·245
,, wet	4·19	
,, first drying ..	2·01	
,, second drying	1·64	

Table showing results of effective resistance measurements with various coils.

In comparing the various insulating materials for supporting the coils, the mechanical properties become important. So far as the electrical qualities are concerned, micanite and ebonite are extremely good; but both are expensive. The former cannot be machined with any hope of regular results, while the latter is affected by sunlight, begins to soften at about 100°C., warps and deteriorates slowly and, more important still, blunts with extraordinary rapidity all tools with which it comes in contact.

Next in electrical properties come glass, marble, varnished papers, the phenolic

* If, however, the distance between centres of wires remains constant, the use of smaller wire may give an improvement, as a larger proportion of the dielectric between wires will be air.—Ed. E.W. & W.E.

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insulating materials, and wood. Glass and marble are hardly suitable for coils. The power factor and dielectric constant are probably of the same order of magnitude for good varnished papers and phenolic insulating materials, but some samples of the former are extraordinarily bad, and they have a further defect in absorbing moisture, which has a very detrimental effect on their electrical properties. The phenolic insulating materials have a power factor varying from 0.03 to 0.07, while the dielectric constant varies from 4.5 to 6 for the laminated materials and from 5 to 7.5 for the moulded. Age does not appear to affect them, and they absorb but little moisture. The laminated products resist shocks, but the moulded material is brittle and difficult to machine; it can, however, be moulded accurately to shape. I have no figures of the electrical properties of wood, but from personal experience I can say that most kinds of wood appear to be good, especially when dry and waxed.

It is a remarkable fact that the power factors of most insulating materials do not vary very much over a large range of frequency. The results of G. E. Bairsto seem an exception to this rule, but the papers of Schott and Dellinger and Preston of the Bureau of Standards show this very well. Some samples have a power factor which increases with frequency; in others it falls, while in others there appears either a maximum or a minimum: but on the whole the variation of power factor is comparatively small. With regard to the dielectric constant, all the results show a very small and regular decrease with increasing frequency.

From the test described above, the best insulation to be put directly on the wires appears to be silk, with enamel as a good second. With enamel, however, there is a tendency to place the wires in very close proximity to each other, and this will increase the self-capacity. Cotton is the worst of the three and is appallingly bad when moist. Further tests are necessary before a more definite judgment can be passed on these materials.

There is one more point I wish to emphasise: that the true criterion of a dielectric is not its power factor but the product of the power factor and the dielectric constant. This does not appear to be generally recognised; although the value of the power factor and the dielectric constant are often mentioned together, it appears to be due more to the fact that, when measuring the power factor of a dielectric at radio-frequency, it is very easy to measure the dielectric constant, than to the thought that the product is necessary in order to compare the relative merits of the samples under test. (*See end of article.*)

For high class work, then, silk covered, or if possible bare wire, wound on an ebonite frame kept away from sunlight can safely be used. The wires should also be well spaced in order to reduce the self capacity of the coil. (The spacing of the turns will incidentally reduce the resistance of the coil for other reasons.) For many coils, however, phenolic insulating materials or even wood could replace ebonite without causing an undue increase in resistance.

APPENDIX A.

EQUIVALENT RESISTANCE AND INDUCTANCE OF A COIL REPRESENTED BY THE CIRCUIT OF FIG. 3.

The impedances of the two parallel branches are

$$R + La \text{ and } r + \frac{1}{Ca}$$

where $a = j\omega$

Hence the impedance Z of the circuit is given by

$$\frac{1}{Z} = \frac{1}{R + La} + \frac{1}{r + \frac{1}{Ca}} = \frac{(1 - LC\omega^2) + (R + r)Ca}{R - rLC\omega^2 + (RrC + L)a}$$

$$\therefore Z = \frac{[(1 - LC\omega^2) - (R + r)Ca]\,[R - rLC\omega^2 + (RrC + L)a]}{(1 - LC\omega^2)^2 + (R + r)^2C^2\omega^2}$$

$$= \frac{(R + rC^2\omega^2)(L^2\omega^2 + R^2 + rR) + [L(1 - LC\omega^2) - C(R^2r^2LC\omega^2)]\,a}{(1 - LC\omega^2)^2 + (R + r)^2C^2\omega^2}$$

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Hence, if R_0 and L_0 are the equivalent effective resistance and inductance of the circuit, we have

$$R_0 = \frac{R + rC^2\omega^2(L^2\omega^2 + R^2 + rR)}{(1 - LC\omega^2)^2 + (R + r)^2C^2\omega^2}$$

and

$$L_0 = \frac{L(1 - LC\omega^2) - C(R^2 - r^2LC\omega^2)}{(1 - LC\omega^2)^2 + (R + r)^2C^2\omega^2}$$

APPENDIX B.

BY THE EDITOR.

In accordance with Mr. Wilmotte's suggestion, we have obtained such information as we can as to the dielectric constants of the dielectrics given in the table in E.W. & W.E., Mar. 1925, p. 325, and we reprint the greater part of the table herewith, having added approximate electric constants, and also the product called KP, by Mr. Wilmotte, which we prefer to call $K\psi$ as ψ is used generally for phase difference (which equals power factor when both are small). For notes on these materials, refer to the original table.

Material.	Power Factor. ψ	Dielectric Constant. K.	Wilmotte Factor. $K\psi$.
Bakelite ..	·046	5	·230
Celeron ..	·057	5*	·285*
Celluloid ..	·035	6*	·210*
Ebonite ..	·010	2.5	·025
Fibre	·050	4*	·200*
Formica ..	·050	5	·250
Glass	·008	6*	·048*
Mica	·000 4	8*	·003 2*
,, built up	·016	6	·96
Paper, waxed	·020	3·5	·070
Sulphur ..	·006	3	·018
Varnish ..	·004	3*	·012*
Wax, paraffin	·00016	2	·00032
Wood, dry ..	·040	5*	·200*
,, baked and waxed ..	·020	5*	·100*

* Variable.

A Transmitting Circuit for Short Wave-Lengths. [R423·0124

By E. H. Robinson.

THE object of the present article is to put before readers who are interested in short-wave working a circuit which the writer has devised for energising an aerial below its fundamental wave-length. It is only fair to state at the outset that the fundamental idea was used several years ago in certain ship spark sets, but the possibility of its application to modern valve transmitters seems to have been overlooked.

The original spark transmitter arrangement is shown in its simplest form in Fig. 1. The aerial is a large ship's aerial, having a natural wave-length of perhaps 400 metres. The loading inductance L_1 tunes the aerial up to the 600-metre wave, the condenser C remaining disconnected for this wave-length. L_1 is the coupling coil from the closed circuit which is tuned to the desired wave-length in the usual way. Now, to get down to 300 metres the switch S is closed, *thus putting the condenser C in parallel with the A.T.I.*, the closed circuit being, of course, re-adjusted to 300 metres. It seems at first very much of a paradox that the introduction of a parallel condenser should cause the aerial to resonate at a lower wave-length than the fundamental, but the fact remains that it does, provided, of course, that C and L_1 are of suitable values. The explanation which has been suggested is illustrated in Fig. 2. Consider the parallel shortening condenser made up of two smaller ones, C_1 and C_2 in parallel; this will be admitted as perfectly permissible. One condenser C_1 may be considered a series condenser straight

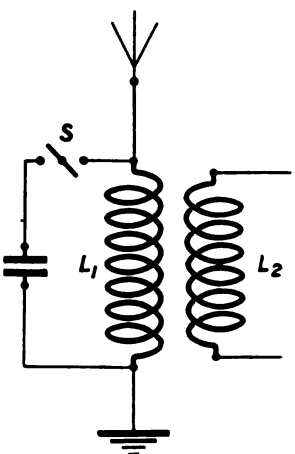

Fig. 1.

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in a plain aerial, thus reducing the wave-length below the fundamental, while the other condenser C_2 forms a closed circuit with L_1, which is tuned to the aerial and conductively coupled to it across the terminal of C_1. We thus have a circuit for working an aerial below its fundamental which differs from all others in that the aerial circuit virtually consists of an aerial with a condenser in series and no series loading inductance at all. This would seem to be the most logical way of working on wave-lengths shorter than that of the aerial itself. What we usually do is to insert a series condenser to get the wave-length down, and then, in order that the aerial may be coupled to some source of oscillations we proceed to load it up again with a coupling inductance which to some extent defeats the purpose of the series condenser.

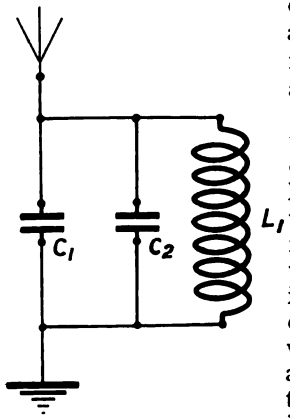

Fig. 2.

The practical circuit adopted for valve transmission is shown in Fig. 3. There is actually no great departure from the usual valve transmitter employing a grid reaction coil. It is essential, however, to tune the grid circuit to the wave-length on which the set is required to function. The reason, apart from the maintenance of a steady wave, is that there are two wave-lengths to which the aerial circuit will respond, namely, the obvious one well above the fundamental which is normally to be expected with a parallel tuned aerial circuit, and the paradoxical wave-length below the fundamental which has been referred to in the preceding paragraph. The grid circuit may contain a small cylindrical inductance with a variable condenser across it. It is well to calibrate the grid circuit roughly against a wave-meter and set it at the required short wave-length and then to adjust the other circuits accordingly. These other adjustments consist mainly in getting the right number of turns of the inductance L in the aerial circuit and adjusting the condenser C. The position of the anode tap is of importance as in any other valve oscillator circuit. By varying the grid tuning condenser without altering any other part of the transmitter it will be found that there are two settings at which maximum aerial current is obtained, and care must be taken to work on the lower one.

The right values of condenser and inductance in the aerial exciting circuit depend so largely on the individual aerial and the wave-length on which it is desired to excite the aerial, that no definite figures can be given here to meet all cases. The following details, however, apply to the experiments made by the writer and may serve as a guide. The aerial itself was about 120 ft. long, consisting of a single length of 7/22 stranded copper wire with an average height of 40 ft. The natural wave-length of the aerial when connected straight to the earth was about 140 metres. It was desired to transmit on a wave-length of 100 metres, and the circuit in Fig. 3 was adopted. The condenser C in the aerial circuit was a .001μF variable condenser at about half setting

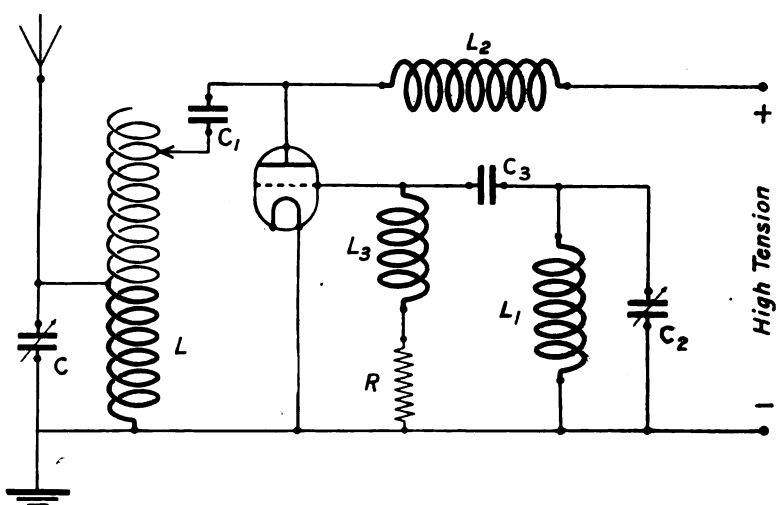

Fig. 3.

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The potentials set up across this condenser are not excessive, and an ordinary receiving variable condenser serves quite well on powers below 50 watts. The part of the inductance L included in the aerial circuit consisted of nine turns of No. 12 copper wire wound on a cardboard cylinder 4 ins. in diameter, the turns being spaced from each other by a distance equal to the diameter of the wire. The anode tap portion was wound with about a dozen turns of 28 D.C.C. wire so as to form a continuation of the thick-wire part; there is no object in using heavy gauges of wire for anode tap or ratio tap windings as they do not have to carry large currents. It is important to have just the right amount of anode tap; this amount can only be found by trial and usually consists of quite a large number of turns. Other components in the circuit, such as the blocking condenser C_1, the grid condenser C_3, the grid choke L_3 and the grid-leak R need no special mention as they were the same as would be required in any other circuit. In the actual experiments made it was found that there was no need to couple the grid circuit to the anode circuit. When the two circuits were brought into resonance, the inter-electrode capacity of the valve was sufficient to maintain oscillations, and nothing was gained by further coupling. The best results were obtained on about 110 metres, although the circuit worked well over quite a wide range of wave-lengths. Obviously the optimum wave-length for such a circuit depends on the dimensions of the aerial. Roughly speaking, its useful range is from somewhat above half the natural wave-length of the aerial to a little below the natural wave-length itself.

A further slight modification shown in Fig. 4 allows additional flexibility in wave-length adjustment. This consists in taking the aerial tapping a turn or two below the upper tapping to the condenser instead of at the same point as in Fig. 3. The effect of taking this lower aerial tap is to *increase the wave-length*; and if the aerial tap were taken from the very bottom turn of the inductance the wave-length would be brought practically up to the fundamental or natural wave-length of the aerial.

It should be remembered that the circuit is not intended to work above the fundamental. The fact that the parallel-tuned aerial circuit is capable of responding to two different frequencies, as stated, might give rise to the suggestion that two waves would be radiated at once. This, fortunately, is not the case. It was found that only one wave was radiated, this being on the wave-length to which the grid circuit is tuned. There is, of course, the possibility of producing feeble higher harmonics on shorter wave-lengths, but this depends on the working conditions of the oscillator valve just as in any other regenerative circuit.

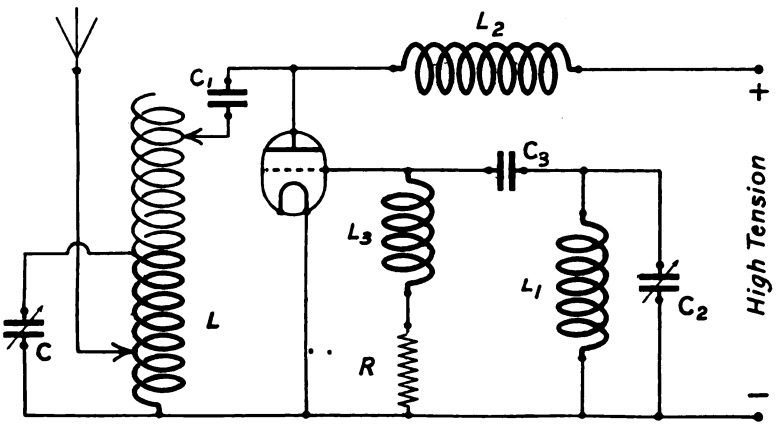

Fig. 4.

Comparative tests showed that the circuit described was quite as good as the more ordinary circuits, and with the aerial used it was distinctly better. In a long high-resistance aerial, at any rate, the measured H.F. current for a given power input was at least 20 per cent. greater than could be obtained with other circuits. Continental stations were worked with quite low power. Whether this method of exciting an aerial can make a general claim to superiority remains to be decided by such other members of the experimental fraternity who care to give it a trial.

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The Testing and Measurement of Wireless Components. [R201·060

A paper read before the Radio Society by Mr. P. K. TURNER, at the Institute of Electrical Engineers, on March 25th.

AN Ordinary General Meeting of the Radio Society of Great Britain was held at the Institute of Electrical Engineers, Victoria Embankment, London, W.C., on Wednesday, March 25th, 1925. Dr. W. H. Eccles presided.

After the minutes of the previous meeting had been taken as read, and signed,

The CHAIRMAN said: The first business is to present the prize to the successful exhibitor at the recent Schools Wireless Exhibition. A great many schools competed for the prize, which was offered by Mr. Reeves (one of the Members of Council). The Broadwater Road School obtained highest marks, and a clear majority over any other school, and, therefore, the prize has been awarded to them by the judges, who were Mr. Maurice Child, Mr. G. G. Blake, and Mr. Fogarty. The prize selected is a loud-speaker with a special winding, and, as the winding is unusual, we are not able to present the instrument to-night. I suppose the apparatus exhibited was made more or less collectively, and not by a single individual.

Mr. FOGARTY: It was the collective work which really gained the marks.

The CHAIRMAN: Is there any spokesman here to represent the School?

There being no representative present,

The CHAIRMAN said: That being the case, all I have to do is to announce that the loud-speaker will be sent, as soon as it is ready, to the Broadwater Road School.

The CHAIRMAN: I will now call upon Mr. P. K. Turner to deliver his lecture, entitled "The Testing and Measurement of Wireless Components."

Mr. P. K. TURNER: This subject, of course, is much too large to cover in a single talk, and I propose just to describe some of my own work. The testing and measurement of wireless components at the present moment is more or less in the making, and one has, in a sense, to invent one's own methods as one goes along.

Of course, one has to face from the beginning some rather large problems in the general idea of measurements. Roughly speaking, there are some measurements that can only be carried out in a highly equipped laboratory — such work, for example, as the measuring of the power factors of dielectrics—but there are other tests which are susceptible to a varying degree of accuracy, according to the conditions under which they are carried out. There is also a third class of measurements which cannot under any conditions be made accurately.

In our own work, of course, we are testing from a particular point of view. My office is constantly receiving commercial apparatus which is intended to be sold to the public, and I am asked to report in the columns of various papers as to whether it is suitable, in one case for the experimenter to use, and, in the other, as to whether it is suitable for the trader to sell; and, of course, reports on the tests vary according to the papers in which they are going to appear.

We have set up as a basis of testing that we will find out what the constants of the article actually are so far as possible before we begin to say whether we think it is to be recommended or not, and the first question that confronts one in considering some component which has arrived for test and report is, "What is it supposed to be or to do?" That is quite a difficult question to answer in some cases. Assuming that we have found out what the component is supposed to do, the next question is, "What are the particular qualities that are desirable in order that it shall do that?" Having solved that question, we have to pass on and say, "How can we measure these

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qualities?" In some cases the methods are well known and obvious, but in others they are not. Before we report we have to answer the question, "How do the results obtained from our tests compare with the results obtained with similar components?" I propose to deal to-night with a few of the most prominent components that we deal with, and to try to put forward my ideas —my personal ideas, and not official ones— as to the answers to these questions.

Naturally, the first accessory that we take up is the valve. In answer to the first question, as to what the valve is for, there are obviously two purposes; namely, amplification and detection. The second question, as to what are the desirable qualities of a valve for L.F. amplifying, is surprisingly difficult to answer. You are tempted to say at first that what you want is amplification—high μ—but high-μ valves are sometimes quite undesirable for that purpose. The valve must be capable of amplifying without distortion, or with not more than a certain maximum of distortion, and it must, for most purposes, be so designed that one can amplify under distortionless conditions with reasonable convenience—that is, without demanding excessive inputs to the valve in the way of high tension, low tension, and so-forth. The first essential of all, amplification, obviously calls for reasonably high μ, but it must not be forgotten that it also involves its anode impedance. The factor μ^2/R_a, the square of the amplification factor divided by the anode impedance, appears to be one that gives a true measure of what the valve will do when it is coupled with transformers designed for it. The absence of distortion calls for a fairly large portion of the characteristic curve of the valve to be reasonably straight, though there can be a certain amount of deviation before the resulting distortion is perceptible. Another most important requirement, and one which is very badly neglected at the present day, is sufficient output, so that the straight portion of the curve should be obtainable at fairly low anode voltages.

Fig. 1 shows a typical curve of the type that I usually work with. I very rarely use the grid voltage characteristic at all, as I find that this is a much more satisfactory method of dealing with the matter. This characteristic is obtained in the simplest possible way, by simply putting instruments into a valve circuit, gradually increasing the anode voltage, and observing the resulting anode current. The first thing about it is the direct measurement it gives of the anode impedance. You have here a certain change of current ΔI_a produced by a given change of anode voltage ΔE_a. If you are on a substantially straight portion of your valve curve, by dividing one by the other you get the anode impedance. There

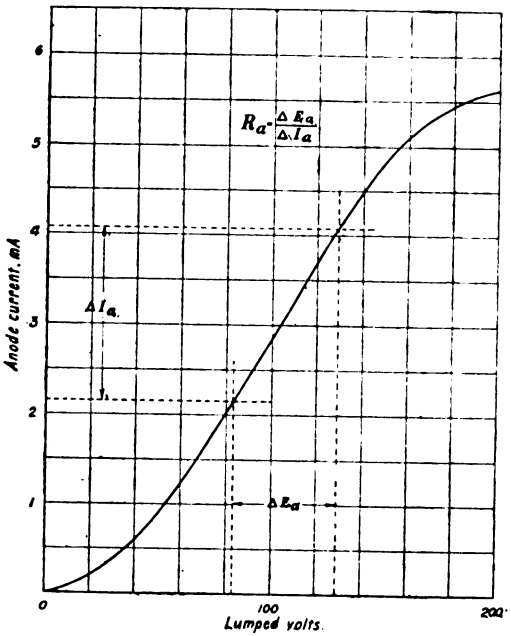

Fig. 1.

is quite an important point there, and that is the question as to on what part of this curve are you going to take the measure of anode impedance? That is a point I shall return to later, but at the moment I might just say that, where the valve gives a curve which begins to rise fairly gently, and goes on gently for a long time, and perhaps does not begin to straighten out until the 100-volt point, it means that, in order to work on the straight part of the curve you must have 150 volts, or something of that sort, and this must be the volts on the *anode* and not necessarily the *battery* volts. In average use the valves of the present day seem to have rather lower voltages than that. The temptation is to use a 60-volt battery unit, and it is quite probable that the valve will

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be used on some point down on the curved part in that case, and the valve maker will usually measure the anode impedance down there. He claims that he is justified in doing so because it is where the valve is to be used. Personally, I give the anode impedance about the centre of the straight part, because I say that is where the valve *ought* to be used. Each has an entirely different point of view, and on one or two occasions that has led to considerable discussion.

Fig. 2 shows characteristic curves for the same valve, but at different filament heats, and this is a point which is badly neglected in the makers' usual characteristic curves of valves. The point, I think, is sufficiently obvious. There is a change in the anode impedance with change in filament heat. The slope of the curve is less with lower filament heats, and the result is a higher figure for anode impedance. But, much more important than that, is the fact that you cannot get the same amount of power output with low filament heat. The instructions so often issued for the use of valves are: "In order to get long life, reduce the filament heat until you begin to lose signal strength." Consideration will show, however, that before there is any perceptible loss of signal strength, you will be working

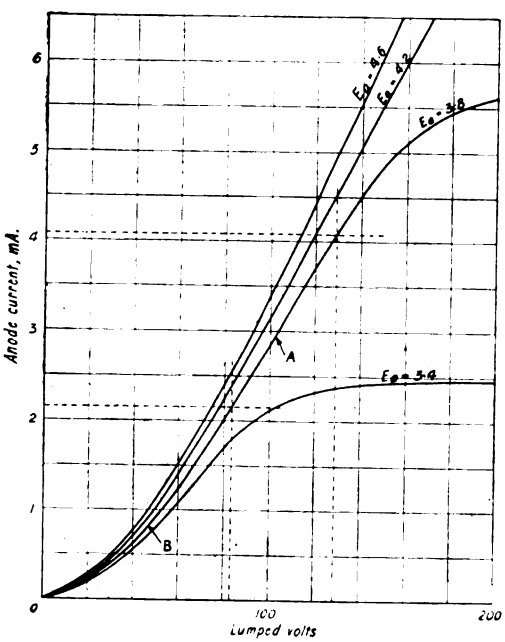

Fig. 2.

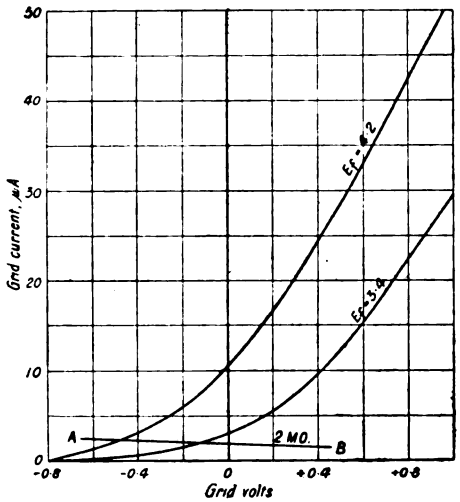

Fig. 3.

right on to the bends of the curves, getting distortion. Distortion becomes perceptible before signal strength begins to fall, and hence that suggestion to cut down the filament heat to that extent is a faulty one from the point of view of first-class reception.

The next constant of the valve cannot be got from this curve, but it is got from the usual grid voltage curve. In our case, having taken these curves—say we take the one for 3.8 volts in Fig. 2—the centre point is at *A*, and we see what the current is. In this case it is 3 milliamperes. With that filament heat and 3 milliamperes, we know we are operating as far as possible on the best portion of our curve for amplification. I then put in 1 volt of negative grid bias, and increase the high tension to come back to the same point, where I am still reading 3 milliamperes. I then first take off the 1 volt and then put on 2 volts grid bias, to get the change of anode current per grid volt. That is, of course, the mutual conductance. The anode impedance is defined as the change of anode voltage per milliampere; or, strictly speaking, per ampere. When one considers that, it is fairly easy to see that the product of those two factors gives us the magnification of the valve. In one case you are measuring the change of anode volts necessary to give a

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certain change of anode current, and in the other case you are measuring the amount of grid volts necessary to give a certain change in anode current. One is expressed as the impedance, and the other is placed the other way up as a conductance. Multiplying the two gives us the change of grid volts which is equivalent to a given change in anode volts, and thereby gives us the magnification.

Then we come to another point. Suppose that this valve, measured at *A*, gives an anode impedance of, say, 20 000 ohms, and that, multiplied by a certain mutual conductivity, gives a certain μ. If you measure the anode impedance down at the point *B*, it will appear much higher, and on multiplying that by the mutual conductivity, you will get a magnification twice as large as before. It appears that this valve is a very fine amplifier, simply because you have measured anode impedance at what I consider to be an unjustifiable point; so that when somebody says that a certain valve has an anode impedance of so much and a μ of so much, the first question to be asked is: at what filament heat did they measure it? and the second, was it measured in the middle of the curve? The middle of the curve seems to be the only point of the curve which you can define accurately. You can take a simple approximation by saying half saturation current.

The question of output I have already dealt with.

For valves for high frequency amplification the conditions are rather different. It is probable that the valve will not be used with a coupling which steps up; hence, a high μ in the valve itself is important. But it is important also to remember that a high magnification in the valve leads to a high input capacity, other things being equal. The effective input capacity of a valve at high frequencies is, to a first approximation, equal to the actual measured low frequency capacity of the valve multiplied by μ. If you have a valve of twice the magnification, the effective input capacity will be somewhere about twice as much, even with the same electrodes. That input capacity has an important effect upon amplification, and it may be that the high μ valve will give less amplification over the whole stage than one of lower μ.

Another point we take into account in getting these characteristics is grid current. Fig. 3 shows a couple of typical grid current curves taken at different filament heats. You are probably aware of the method of finding what is going to be the actual grid voltage of the detector valve when it is in

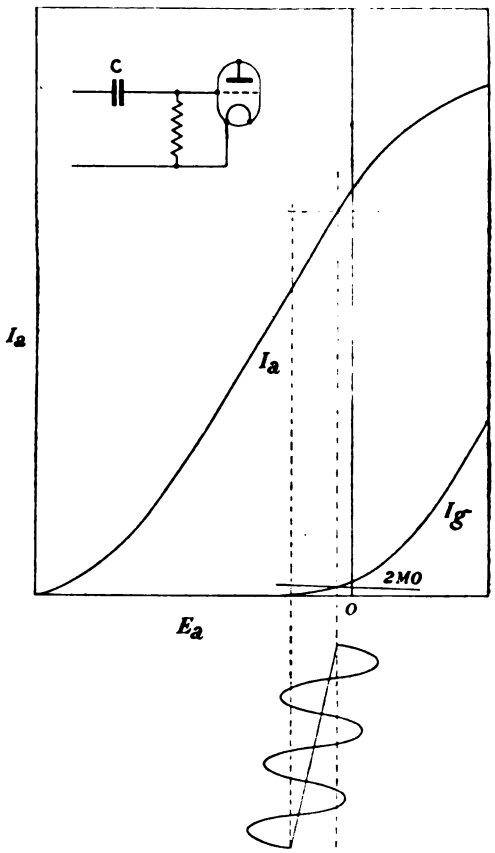

Fig. 4.

use. We all know that it is possible to draw a line *AB* in Fig. 3 on the curve sheet, representing the current and voltage conditions across the grid-leak, while the curve represents the current and voltage conditions across the grid space inside the valve. The point where they meet is the voltage at which the grid will set itself when no signals are coming in. Fig. 4 is the circuit we all know. We have to think what are the desirable qualities in the valve in order to get the best results. First the question arises as to how quickly the potential of the grid will fall. It seems

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likely that it will eventually fall to an amount equal to the input voltage, or very nearly so. But the speed at which it will follow the changes in incoming potential is governed by two things. It is mainly a question of how quickly the condenser C charges up, and that depends upon the size of the condenser, and on how much current is passed during a positive swing. A quick rise in grid current would appear to be an advantage. Then the question arises—granted you have got so much voltage drop on the grid—how much change in anode current is that going to give? and that is a function

TYPICAL VALVE CONSTANTS AT RATED FILAMENT VOLTS						
Class No.	Description	Saturtn. Current I_s (mA)	Anode Impedance R_a (O)	Voltage Amplifctn μ	Power Amplifctn $\frac{\mu^2}{R_a}$	Filament Efficiency $\frac{I_s}{I_f}$ (mA)
460	"R"	8	25 000	7	2	3
460,560	New Bright General Purpose	15	20 000	7	2½	6
306	"06" Type	78	18 000	7	2½-3	30
235	"Semi-dull"	15	18 000	7	2½-3	15
245	2 Volt. Power	25	15 000	5½	2	26
606	"06." Power	40	7 000	8	9	60
625	Power	50	5 000	7	10	30
625 b	"High μ"	40	20 000	20	20	30
435	4 Volt, Power	40	10 000	7	5	30

Fig. 5.

of the slope of the curve marked I_a. I think we can say that a quick rise of grid current is an important thing, and that the other important thing is the ratio of μ to the anode impedance.

In addition to these measurable points, there are a lot of other things affecting the quality of the valve. We have to consider whether it is robust, regular—are alleged duplicates really duplicates?—to what extent it is microphonic, what it costs, and so on. These are not capable of measurement, and I do not propose to deal with them to-night.

I will give a few typical results. (See Table, Fig. 5.) These are mostly the average of two or three valves of that general nature. The first column is a little personal fad of my own, namely, a class number for a valve. Different makers have initials for different types of valves, and they also have numbers. One maker calls a given type of valve one thing, another maker another, and yet another maker another, and so forth, and one gets them very badly mixed. I propose to give all valves of a certain description a number, of which the first figure gives the approximate rated filament volts, and the others the approximate rated filament amps.

You can say roughly that, since the straightness of curves of valves do not vary a very great deal, the undistorted output is proportional to the saturation current. Therefore it gives a very good idea of what any valve will do. In the sixth column we have μ^2/R_a multiplied by 1 000, and in the seventh a rather useful figure, the filament efficiency. It is the milliamperes of saturation current given by 1 watt applied to the filament. The old R valve gives 3 milliamperes per watt, but modern bright valves give more, about 6, and new dull emitter valves about 30. The "semi-dull" valve runs to 15, and the "606" type of power valve runs to 60. If the filament is of a new type altogether this figure gives you an idea of its comparative efficiency from the point of view of emission. If, on the other hand, the filament is one of a known type, and you find it gives an extra high value of filament efficiency, you can guess that it is being run rather hot. If somebody gives me an ordinary R valve with an ordinary bright filament, and says that the filament efficiency comes to 10, I should say that while this is very nice, the life of the valve will be about 150 hours, and I should not recommend it. Thus, that is a point quite worth watching.

Inductance Coils.

I will now break away from valves and come to the question of coils—a rather neglected component. Hundreds of them are made, but very few appear to be tested. The first question is, "What is it for?" It is a pure inductance in theory—or it is supposed to be. What are the desiderata? The first one, apart from efficiency, is that it should be fairly rigid and fairly constant. How rigid and constant you want it depends upon its use. If for use in an ordinary receiving set it does not much matter, but in a wavemeter you must go out for those two factors, even at considerable cost. Another feature about which a great deal is said in advertising matter is low self-capacity. My own opinion is that low self-capacity is nothing like so important as it is often claimed to be.

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People talk of the apparent resistance of a coil going up enormously with high self-capacity. If you have a circuit like *B* in Fig. 6 in which you induce from a source into another circuit, and in series with the inducing coil you have another coil *L*, then the coil *L* naturally has a self-capacity, represented by the dotted condenser *C*. When you happen to strike the natural frequency of the circuit *LC*, obviously that is a rejector circuit, and its apparent resistance will go up. But it is a comparatively rare thing, and in a case like that of *A* in Fig. 6, where you are inducing into the coil itself, it does not arise at all. It is only under the conditions of circuit *B* that self-capacity is a hindrance from that point of view. Of course, it is always a hindrance, in diminishing the range with which you can swing with a given condenser, but even that may be over-rated. Remembering that most condensers have a capacity, when set at zero, considerably greater than that of good coils, you still have to combat the self-capacity in the rest of the circuit, however good the coil.

Now we come to resistance, and this, I think, is probably the most important quality. The subject was dealt with so admirably by Prof. Fortescue at the last meeting of the Society that there is not much to be said about it, except that I propose to describe some methods of measurement.

Our standard third question is: How are we going to measure these things? Of course, there are dozens of ways of measuring an inductance, but I think it will be generally

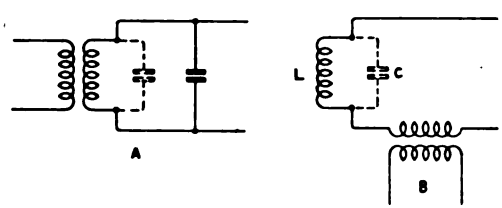

Fig. 6.

agreed that inductances, for our purposes, should be measured at or about the frequency at which they are going to be used.

We all know the fairly simple method of measuring the true inductance and self-capacity of a coil. You place across the coil a variable condenser, of which you know the capacity. From the old formula we know that the product of the inductance and the total capacity across it is proportional to $\lambda^2/3\,550$, the wave-length being obtained by testing with the wave-meter. You measure the wave-length with a varying amount of capacity added, plot the results as shown by dots in Fig. 7, and, if you are in a hurry, you draw what appears to be the best straight line through them, and then the distance *AO* represents the self-capacity of the coil. The alternative, and superior method, is to make equations and work them out by the method of least squares, to get the most probable values and the probable errors. That, unfortunately, means a lot of work, and I do it on my own standard coils, but I do not mind admitting that I do not do it for anybody else's. (Laughter.)

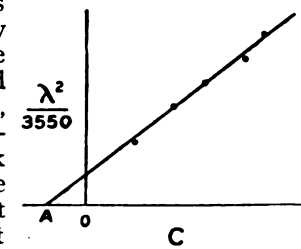

Fig. 7.

That brings me to another point, and that is the lack of information—and I must try to remedy it—on the interpretation of results of this sort of work, and on computation. There are dozens of fine books on calculus, advanced and elementary, and books on the theory of wireless, but I do not know of a single book dealing with methods of numerical computation, in reducing results to a practical form. If anybody has done any of that work, I beg and pray him to write a book, or some articles on it.

As to measuring the high-frequency resistance of coils, the methods, I think, are pretty well known. I described two or three recently. The difficulty is that as a rule you cannot measure the high-frequency resistance of a coil as such. You can find the apparent high-frequency resistance of a circuit, but, of course, as Professor Fortescue pointed out, that apparent resistance includes all sources of power loss. Recently some measurements were made at the National Physical Laboratory, in which they did find the resistance of a coil as an individual thing by itself, and in rather an

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ingenious manner. They made the coil of glass tubing, and filled it with mercury, and used the mercury inside the tube as the coil. They then put the coil into an oven, and calibrated it as a thermometer against a standard thermometer. Then they put it in a circuit and found what increase of temperature resulted in the coil from a definite amount of power going in, and hence found its resistance by itself. It was

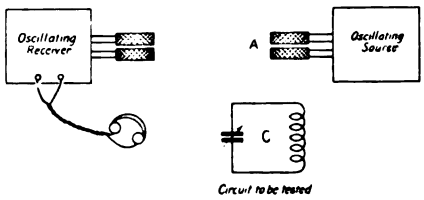

Fig. 8.

interesting to note that when they came to check these results they did not check at first.

Previously they had had a circuit consisting of one or two wires, the coil and a condenser. They thought they had measured the condenser resistance fairly accurately, and they had found this method of measuring the coil resistance fairly accurate. Eventually they ran a blowpipe flame over the plates of the condenser, and they did then get a check. The running of the blowpipe flame over the plates of the condenser reduced the resistance by between 1/20th and 1/10th of an ohm in that instance. What they did actually was to burn the dust off the plates. They came to the conclusion that under the repeated input and output of power these dust particles were moving; they were standing to attention and then lying down again, and the power taken to pick them up and lay them down again was being registered as the apparent resistance. That was the discrepancy.

Coming to the actual subject, you put a given coil in a circuit and you measure the H.F. current induced in it. You then insert in the circuit a known resistance, and measure the current. Obviously, if the circuit itself already has 10 ohms resistance, then the adding of 1 ohm will not make much difference to the current; if it has only 1 ohm resistance, the adding of 1 ohm makes a considerable reduction in the current. That is the whole essence of the resistance variation method. The well-known alternative method is that commonly known as reactance variation. That consists simply of measuring the sharpness of the resonance curve. There are two rather interesting new methods which you may not all have come into contact with. I will mention particularly one which has rather special advantages. This is the invention of P. W. Willans. You put up an oscillating source, as in Fig. 8, and you put near it your circuit to be tested, so that you couple it to the two coils. Some distance away you put up an oscillating receiver. That also has two coils. The coils *A* and that to be tested form a transformer. When you tune *C* through the wave-length to which the source is set, you alter the current in *C*. But it is always the case that when you alter the load on the secondary of the transformer you alter the apparent impedance of the primary. But if you are altering the apparent impedance of coils *A*, which govern the frequency of the source, then you are altering the emitted wave-length, and if you have the receiver beating with it, you alter the audible note. As *C* swings through resonance, your note suddenly gets higher, and then gets lower, and as you get further away from resonance it again becomes normal. Willans showed that if you measure accurately the condenser adjustments of *C* at which the note is at its highest and its lowest in pitch, you can find quite easily the resistance of the circuit *C*.

There is practically no calculation required. You can do it in various ways. You can either work from a known frequency, and have the condenser of *C* calibrated, or you can insert resistance into the circuit and use this beating arrangement instead of the meter in the resistance variation method I have already described. I have been able to show that you need not even have a calibrated condenser at *C*, provided you have a *good* condenser. So far as my knowledge goes, Mr. Willans is the first man to describe a method of high frequency resistance measurement which does not require any calibrated condenser or any high frequency ammeter or voltmeter. It is a method which can be handled by practically any ammeter.

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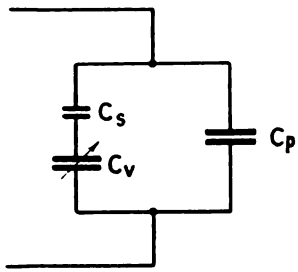
There is another method, susceptible of considerable accuracy, which is allied to this. It is the Mallet-Blumlein method, which has been described before the Institute of Electrical Engineers. Instead of having the coil of C coupled to both the coils of the source, it is coupled to an extra coil in the anode circuit, so that the reaction from it would not interfere with the frequency. But it did affect the impedance of the coil to which it was coupled, and by measuring that impedance, and by adopting a certain graphical construction, you can come to a very accurate measurement indeed of the resistance. That is essentially a laboratory method, and, as such, is rather beyond the scope of my paper to-night.

There are one or two little points I should like to mention. In these and the reactance variation methods the total changes are about 2 or 3 degrees on the average condenser scale, and that makes it awkward: the accuracy required is of the order of accuracy of the scale itself. There is a very old method of getting over that, and that is by a group of condensers. You want to be able to alter condenser C in Fig. 8 by 1 per cent. or less. You simply put in parallel with it a small condenser, about 1/10th its capacity, and in series with that you put your variable, a big variable, as in Fig. 9*a*.



$$C = C_p + \frac{1}{\frac{1}{C_s} + \frac{1}{C_v}} = C_p + \frac{C_s C_v}{C_s + C_v}$$

Fig. 9*a*.

When you reduce C_v to zero, C_s is cut out, and the capacity is simply the capacity of C_p. However big C_v may be, the capacity of C_s and C_v in series can never be greater than that of C_s, and therefore the total change you can make by varying C_v from 0 to infinity is, you can say, not more than 10 per cent. That is a very old tip, of course.

As to high frequency resistance units, Fig. 9*b* shows the ones I am using. You probably know that Messrs. Burndept make a little gadget for use with dull-emitter valves; a fixed resistance which screws into a socket.

The standard method of use is to lead a wire in at the base and up the groove to the top, and then wind it round and round the outside and finish it off. That struck me as having possibilities. I have obtained a few of these through the courtesy of Mr. Phillips, of the Burndept Company. I set in at A a piece of 40-gauge copper wire, join it at B to anything from ½ to 2 in. of 47 Eureka, follow this with 40 copper again, solder at C, and cover the whole thing up.

These have a great many of the special properties required in a resistor for high frequency resistance. I should say that the inductance is probably less than 1/100th of a microhenry, and the capacity is of the order of one or two centimetres. In any case, the change in reactance from one resistance to another is extremely small. I assume they make no change in the inductance or capacity. The weak point is that there is contact with red fibre, which is, for these purposes, not a first-class dielectric. Owing to the power loss in the dielectric, you cannot be certain that the high frequency resistance will be absolutely the same as the measured D.C. resistance.

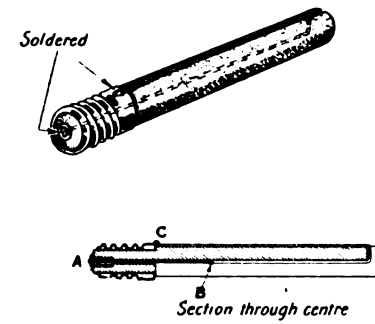


Fig. 9*b*.

The next thing, unless you adopt the Willans method of measuring high frequency resistance, is the measuring instrument—the ammeter. That is quite a difficult question. A thermo-junction is obviously indicated, but if one is using a rather insensitive measurer of current in the circuit one must either couple closely to the source

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or use a high power source, in order to get sufficient current in the circuit to get readings.

But on no account must one couple closely to the source, because the whole theory of that method of measurement is based on the fact that the source of supply is unchanged. If we couple closely the reaction of the change in current induced in the circuit affects the source. Thus we must have a large source. A large source is not convenient, especially in the drawing-room where I usually work, so that I came down from the ordinary hot-wire meter to a delicate thermo-junction. But on connecting up the circuit you are likely to get a little surge of current, and before the pointer of the galvanometer has begun to move and show the surge, the thermo-junction has burned out. Besides, delicate thermo-junctions have quite high resistances. Eventually I fell back on the Moullin voltmeter. It is quite easy to show that the measurement with a Moullin voltmeter of the volts across the coil or a condenser in a resistance circuit is exactly equivalent to measuring the current in the circuit. Moullin voltmeters are of two kinds.

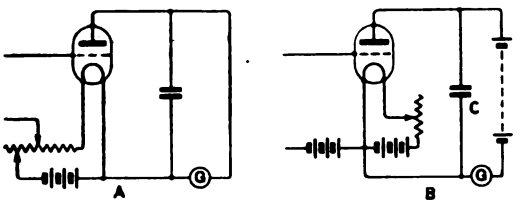

Fig. 10.

Each is simply a calibrated valve detector —there is the type with grid-leak and condenser, and the type without. In measuring high frequency resistance the first thing I wanted to ensure was that the load put on by the detector itself (the voltmeter), should be the smallest possible, and therefore I plumped for the anode rectification type. That is usually made up something like *A*, Fig. 10. There is a small grid bias caused by the drop across the resistance, and there is no high tension battery beyond the six volts of the accumulator. It appeared to me that we have not got to the lowest power absorption. With the source I had at my disposal I got a deflection of 3 or 4 volts. I therefore put in a 4½-volt grid battery, and, to get readable current in the galvanometer, I had to put on some anode voltage, the circuit then being as *B*, Fig. 10. Rough measurements I have taken indicate that that voltmeter, very roughly made, throws into the circuit about 9 micromicrofarads of capacity, and it increases the apparent series resistance of the circuit by about 0.6 ohms. I am pretty well sure that one fairly well designed will come down to considerably less than that. It is important to make sure that the condenser *C* is very large. The point about the condenser is that (owing to the well-known Miller effect), if the valve has a load in the anode circuit, its input capacity and resistance depends upon that load. By making *C* a very large condenser you practically short-circuit that load, and, for any reasonable frequency, you can say there is no load. The reactance of the condenser is so low that there is no anode load. There is a useful test for that, and that is to measure the apparent input capacity with the valve alight, and with it out. You put two such instruments across the circuit, and use one to take the readings while you connect and disconnect the other, and see what effect it has on the circuit. The first thing to do is to see how much capacity you have to add to the tuning condenser, and secondly, to measure the high frequency resistance of the circuit with and without the extra meter. I am glad to say that in my own instrument I have not found any difference whether the valve was alight or not; hence the capacity was not increased by the load in the anode.

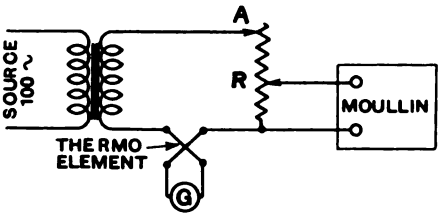

Fig. 11.

There is another little point. The two input leads in the actual arrangement were of stiff copper wire, about 8 inches long, 6 inches apart, and about 5 inches above the table, and, having made the above test, I disconnected at the meter, leaving those two leads on the tuning condenser, and measured again. Then I took them off at the condenser end and measured again. The two grid leads

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threw .1 ohm into the circuit. Whether it was dielectric loss to the table, or whether it was actual radiation, I do not know. Experts have given me opposite opinions. It is interesting to realise that a few inches of copper wire disconnected at one end throw quite a large resistance into the circuit.

As to calibrating the voltmeter, I rigged a local oscillator with a low frequency intervalve transformer across it, and with a condenser across the secondary got about a 100 cycles source. The circuit was as in Fig. 11. What one does is to move A up and down until one gets a convenient current which you know. R is calibrated, and you know exactly what resistance it is; therefore, you know the voltage applied to the Moullin voltmeter. You then measure what deflection the Moullin voltmeter is giving, and, unless something goes wrong, you have it calibrated.

In finding the resistance of a coil you have to correct for the resistance in the rest of the circuit. The resistance of the condenser is the sort of thing with which you must start. I threw the onus of that on the National Physical Laboratory, and they gave me the resistance of my condenser at various settings.

Having found the resistance of a coil, you are confronted with the question of how to express this. It is very variable. The higher the frequency the higher the resistance.

There is a certain confusion between "power factor," "phase angle" and "phase difference." In any case, I think the soundest method is to measure the resistance-reactance ratio of the coil, which is the difference of the phase angle from 90 degrees. The resistance of a coil at high frequency is composed partly of a more or less constant element, the resistance of the wire; partly of skin effect, which I believe varies as the square root of the frequency; and partly of dielectric loss, which probably varies as the square of the frequency. In any case, the resistance is a rather complicated function of frequency. The phase difference, or R/X depends upon the resistance divided by frequency. The resistance is expressed, as in Fig. 12, and if you divide it by frequency, you get an expression for ψ, the phase difference, and it is obvious that this is a minimum when the frequency is $\sqrt{C/A}$. Expressing the same thing in another way, a coil in which the dielectric losses are high is bad for high frequencies, but not so bad for low frequencies, while the reverse is the case for a coil of high ohmic resistance.

I have noticed in the report of Professor Fortescue's paper, that he speaks of coils of 3 ohms per millihenry. I am going to try to get some of those coils, because—I do not know at what frequency he measured them—at broadcast wave-lengths a millihenry has reactance in the neighbourhood of 5 000 ohms. If you put resistance over reactance you get 3 ohms over 5 000 ohms, a phase difference, or whatever you like to call it, of .000 6. Personally, I have never come across any coil like that yet. Typical results for commercial coils sold for amateurs in this country show power factors of about .01—the resistance is 1/100th of the reactance. I worked with some 50 and 35-turn coils not long ago which showed power factors of about .005, and I was very pleased with them until I read this report. At the National Physical Laboratory they have some very fine coils used on the multivibrator wavemeter. The lowest power factor there was .001 8, so that either the resistances of Professor Fortescue's coils must have been measured at very much lower frequencies, or else they were extraordinarily good.

POWER FACTOR OF COILS

Apparent Resistance of coil, including dielectric losses = R

Frequency = f

$$R = af^2 + bf + c,$$

$$\psi = \frac{R}{\omega L}, \text{ or, } \psi \propto Af + B + \frac{C}{f}$$

This is a minimum for $f^2 = \frac{C}{A}$

Fig. 12.

One interesting case cropped up the other day. A coil arrived, of which I thought the design was extraordinarily good. It was of bare wire, with a minimum of supporting

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matter, and it gave every prospect of being excellent. But when I tested it I found its resistance, at broadcast wave-length—377 metres—was in the neighbourhood of 12 ohms

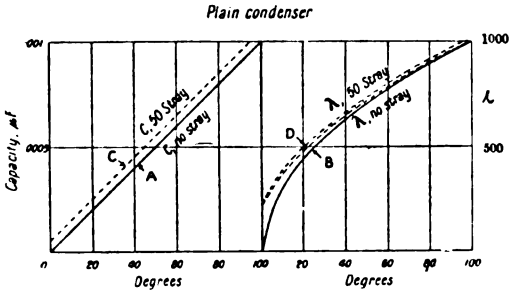

Fig. 13*a*.

as compared with 5 for the very ordinary coil I put against it. I found that in order to hold the outside turn down, they had soldered it to the next previous turn, so that there was one short-circuited turn. I notice that all the makers advertise the self-capacity of their coils, but, unfortunately, they do not tell us much about the high frequency resistance.

Condensers.

The condenser is another all-important component. Here again the answer to the question as to what it is for is a simple one. It is pure capacity, fixed or variable. I suppose one of the first desiderata in the case of a condenser is that it should be constant. I am talking primarily of variable condensers, and I do not think many people realise how difficult it is to get anything like constancy in a variable condenser. I was told the other day, at one of the biggest testing institutions

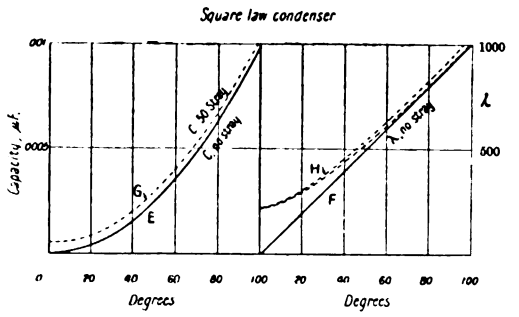

Fig. 13*b*.

in the country, that although they are prepared to pay £200 or £300 for a condenser, they cannot get one that will remain accurate for six months within 0.1 per cent., and in fact, whenever they are doing a job which requires a calibrated variable condenser, they calibrate one for the job. The trouble appears to be largely due to the fact that the plates sag. Of course, one also wants low loss, and, if possible, a low zero, and one also wants, for ordinary listening purposes at any rate, a convenient scale-law—by which I mean a reasonable and comfortable change of capacity in relation to the change of angle which you effect by turning the knob. I am now going to ride another hobby-horse.

Fig. 13*a* shows curves for an ordinary condenser, with semi-circular plates. If it were a perfect condenser, you would have the capacity varying directly with the degrees, as indicated at *A*. When one puts such a condenser with a perfect coil, and works out the resulting wave-length, one

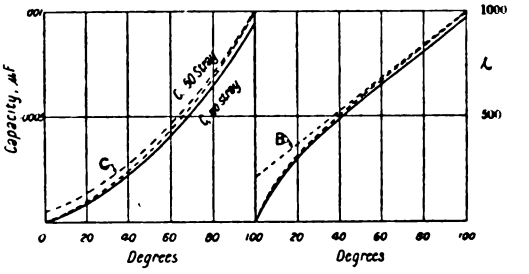

Fig. 14*a*.

gets a curve such as *B*. But actually there is stray capacity, so that *C* and *D* represent actual conditions. Great efforts have been made in the alleged "square law" condenser to get over the curvature of *D*. But in practice they do not.

Fig. 13*b* shows the capacity curves of a "perfect" square law condenser, *E* and *F* being those for no stray capacity. But the effect of stray is to give curves such as *G* and *H*. I have had about a dozen of these to calibrate, and the makers were annoyed when I said the curve looked like *H*. I had to explain why a square law was not a square law. The simple way of getting over it is that we allow for (say) 50 cms. stray capacity, and we say that we know what our wave-length will be—like *B* in Fig. 14*a*—

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and we draw a straight line and then build the condenser to deal with it, and the curve comes out like *C*. Fig. 14*b* shows capacity

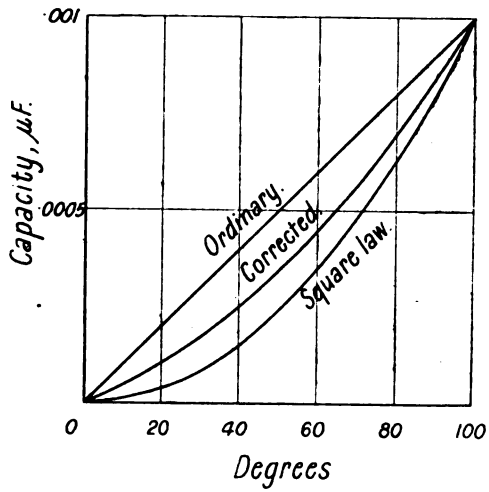

Fig. 14*b*.

curves for the ordinary, the square law, and the corrected square law condenser. Apparently nobody has had the nerve to build a condenser of the corrected type yet, but I hope it will come.

For fixed condensers, which are, as a rule, not air-dielectric, the requisites are of a sufficiently high voltage limit, compactness, low losses, accuracy and constancy. There again one is entirely in the hands of the condenser maker, but there are one or two condenser makers who know how to make condensers, and who fulfil those needs to a considerable extent.

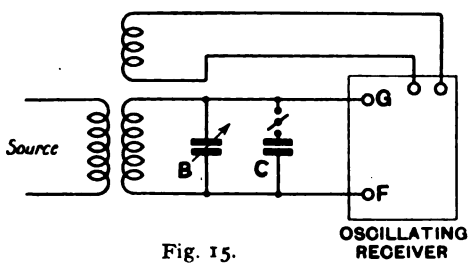

Fig. 15.

I think Fig. 15 shows the simplest and by far the least troublesome method of measuring condensers. We arrange an oscillating receiver, and tune it to the source, then switch in the condenser *C* to be tested, and see how much has to be taken out of the calibrated condenser *B*. That has the advantage that you are making only the very smallest alteration in the circuit. The usual method of detecting resonance is to listen for the silent point between beats: that is sufficiently accurate for most work provided you balance the strength of oscillation in the receiver and the source. If it is found that the silent "point" is too wide, then it is not sufficiently accurate, and the best way out of that is to put up an audio-frequency oscillator, make sure that the telephones are in the output circuit of that audio-oscillator, and adjust the condenser *B*, not to silence, but until the note itself beats with the audio-frequency note.

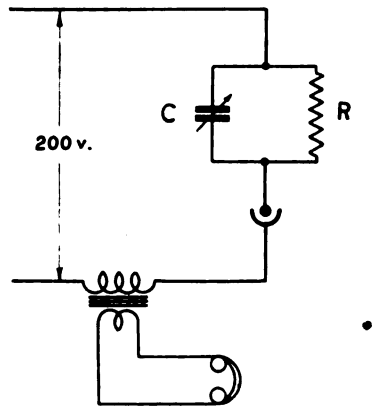

Fig. 16.

A standard method of condenser testing, of course, is to use the alternating current bridge, but an accurate alternating current bridge is extraordinarily expensive, and I prefer to measure large condensers by the "neon tester" method. The method is probably well known to you. If the condenser is sufficiently large it is simply a question of counting the flashes in a neon or "Osglim" lamp with a condenser and high resistance in its circuit (see Fig. 16). The method only compares against a standard, and is not an absolute method. As a general rule, one adopts the same principle as before, putting the unknown condenser in parallel with a calibrated one. For small variable condensers the flashes are so rapid that you get a musical note, and by switching quickly from one condenser to another one can match

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those notes to a surprising degree of accuracy. But the more accurate method is to put up two complete neon tubes in circuits, as in Fig. 17.

Here *A* represents one set with a small condenser. You adjust that circuit until it gives a musical note which beats with the one from *B* and produces slow countable beats in your ear, and, after diminishing the capacity of the unknown condenser and increasing that of the calibrated one, to compensate; again count the slow beats between the musical note of *A* and that of *B*.

The high frequency resistance of a condenser is again a very variable thing. I am told that with a fixed condenser of good quality it is justifiable to assume that the phase difference—the ratio of resistance to reactance—is more or less constant. In the case of a variable condenser the phase difference is inversely proportional to the amount of capacity in; that is to say, if the phase difference is 1 part in 1 000 at 180 degrees, it will be, to a first approximation, 1 part in 100 at 18 degrees.

As to typical results, the zero capacity of most ordinary variable condensers on the market appears to be between 20 and 30$\mu\mu$F. Values of ψ (phase difference)

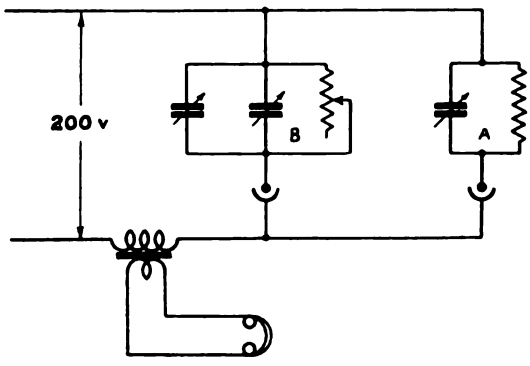

Fig. 17.

seem to be, on the average, in the neighbourhood of .000 2 when the condensers are all in.

The constancy of the ordinary aluminium plate condenser is 2 per cent., if that. Brass plate condensers, possibly, are better, but not much. I distinguish between constancy and accuracy. The constancy is the maintenance of the definite capacity at any given reading at any time, and the accuracy is the approach of the all-in capacity to its rated value. If a .001 condenser measures .001 all in, it is accurate. If, at the end of six months, it was still .001 within 1 per cent., I should think I had a marvellous condenser.

Crystals.

I should like to make a short reference to crystal testing. I cannot give a history of the various methods adopted to try to get

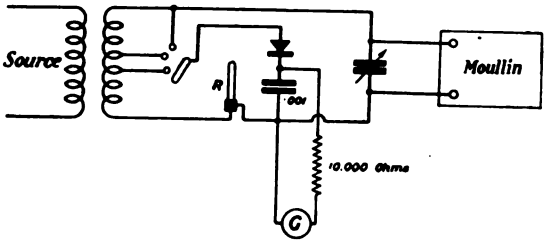

Fig. 18.

some idea of whether a crystal was a good one or not, but finally we decided to measure the high frequency input power on continuous wave and the D.C. output power, and call the ratio the efficiency. I will show the circuit we tested on (Fig. 18).

You are going to measure the high frequency input power of the crystal. That crystal has a resistance, very often, in the neighbourhood of 50 000 ohms, and, to get results of any value you must measure at the signal voltages it is likely to be used on. We are confronted with the job of putting an H.F. voltage of 0.1 to 1.0 volts on to 25 000 ohms, thereby getting a matter of 5 microamperes, and you have to measure 5 microamperes at broadcast wave-length. That cannot be done, so we built up a high frequency resistance testing circuit. Instead of using a thermo-junction, we used the Moullin voltmeter to measure the voltage across the condenser, which is an indication of the current through the circuit. First of all we leave the switch as shown, and insert a little high frequency resistance at *R*, and measure the resistance of the whole circuit. Then, if you put the switch right up on the top stud, you put the crystal in circuit. The effect of that is a power absorption which can be represented as an

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increase in the equivalent series resistance of the circuit, and, of course, a decrease in voltage. But one has to re-tune. The re-tuning must be allowed for, because you are measuring the voltage across a certain reactance. If you vary the reactance you have to allow for the variation. Actually it is so small that the correction is of the order of 1 part in 1 000. We put two tappings on to the coil and calibrated them, so that when we had two or three volts across the whole thing, with a crystal on an intermediate stud, we had exactly 1 volt on the crystal. We calibrated it simply by measuring the volts. So that in that way, while measuring the whole voltage across the circuit, we can apply a definite fraction of that voltage to the crystal, and, of course, measure the resulting current. Now we have the input load expressed as series resistance. It is easy to work out the equivalent high frequency resistance *across* the circuit, and that tells us the apparent high frequency resistance of the crystal, and by multiplying that by the current squared we find the input power. In the same way we find the output power, by multiplying the square of the crystal current by the load in the circuit, 10 000 ohms.

There are one or two results I might show. I do not definitely say that such and such a crystal is magnificent on the basis of the small amount of testing done on one sample. Our tests on these crystals gave the results shown in Fig. 19.

I assume that the average voltages on a crystal in action are .1 to 1. I have actually found one point on one crystal in which the efficiency was 94 per cent. I thought there was something hopelessly wrong with it, and checked it again, and got results varying between 90 and 96. The last

TESTS OF CRYSTALS AT APPROX. 800 kC			
Name	Input Volts	Efficiency	H.F. Resistance
EXOLO	·5 *	29 %	25 000
	1·0	20	13 000
	·5	24	34 000
RADIOLYTE	·5 *	45	15 000
	1·0	40 – 50	5 400
	·1	40 – 50	25 000
DEARNITE	·5 *	67	14 000
	1·0	70	10 000
	·2	70	27 000
ETHITA	·5 *	75	24 000
	1·0	50	7 100
	·1	80	47 000

* Average of 5 contacts

Fig. 19.

column shows the apparent high frequency resistance, and this value may be a useful guide in designing the circuit across which the crystal has to be used. Of course, the power loss in that circuit should be designed in relation to the power loss in the crystal itself. There is always a considerable increase in the high frequency resistance at low voltage. I have also got some results which were obtained last night with a Zincite - Bornite detector. Taking the average of 5 points, with an input of 1 volt, the efficiency was 12 per cent., and the average high frequency resistance was 95 000 ohms. I then found a good point, and at 2 volts input the efficiency was 52 per cent., and the high frequency resistance 25 000 ohms. At .2 volts the efficiency was 5.8 per cent., and the high frequency resistance 220 000 ohms. I cannot guarantee the accuracy of the last figure, because I was on the limits of measurement of my meters, but it is perhaps within 15 per cent.

The Discussion.

The CHAIRMAN: The lecture is an especially interesting one to old experimenters like myself, who were working on these things 20 years ago, and doing very imperfectly the very measurements that Mr. Turner has described—with damped waves because there were no continuous waves and with very imperfect measuring appliances. I remember measuring the efficiency of crystals, I think about 1908, which is 17 years ago, with spark transmission, and getting efficiencies of from 5 to 15 per cent. It seems that these modern crystals, especially when used with continuous waves, have better efficiencies, or perhaps the methods of measurement are now more accurate. Every item discussed by Mr. Turner was intensely interesting, and I have no doubt, if you would allow me, I should ramble on for a very long time talking about each item, but, unfortunately, I have another appointment, and have to leave. I will therefore ask Mr. Coursey to take the Chair.

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Mr. P. R. COURSEY, B.Sc. then occupied the Chair for the remainder of the meeting.

Mr. MAURICE CHILD: The measurements I have made in the past have not been of a very high standard of accuracy, and I have rather fallen out of the method of measuring things with the latest arrangements. I was particularly impressed with the interesting method which the lecturer described of comparing condensers for measuring the capacity of the condensers. He mentioned the very simple device of the neon tube. It is very curious that one of the earliest high frequency measuring instruments ever produced utilised the neon tube as the detector, but, of course, in a different manner from that indicated by the lecturer, although not very different. I refer to the well-known cymometer of Dr. Fleming, in which he employed a neon tube, and I believe that was one of the first applications of that gas in practical service. I think the neon detectors which Mr. Turner referred to were probably the same devices that one sees nowadays adapted for advertising people's goods. I am not quite happy as to whether that method is altogether satisfactory. It seems to me, from observations I have made in connection with the neon tube, that there is a risk of the tube itself failing to operate properly at just the critical time when you want it to operate properly. The characteristics of these neon detectors or lamps are not, I think, well understood at the present time. It seems to me that at some critical voltage they burst off, but before you get that bursting off you get apparently a very weak current, which is not obvious at all. Mr. Turner seems to have got over that difficulty by using the aural method, but I should like to know whether he is absolutely satisfied with the use of these neon detectors for practical purposes, and whether he finds that in the middle of his measurement there is a variation which necessitates his starting all over again. The other points in connection with coils are very interesting, but I am sure other speakers can deal with them better than I. I do think, however, that Mr. Turner has served us very well in bringing out one important thing. He mentioned the test on one coil which he thought was going to give very good results and, fortunately for us, he measured it and found that he did not get good results. The reason he gave was that one turn was short-circuited by another. To members here who have not taken up the study of wireless very long, and whose knowledge of the subject may be comparatively elementary, that is a most interesting thing, because it shows the futility of expecting to get reliable results when you have a coil consisting of a wire wound on a piece of cardboard and finished off or having contact made to it, in such a manner that it short-circuits, not one turn, but sometimes four or five at a time. If the publicity which this lecture will get will have the effect of stopping the manufacture of these inefficient devices, then Mr. Turner will have done us and the public generally a very good service.

Mr. R. E. H. CARPENTER: I was interested in the figure for what Mr. Turner called the "power amplification" μ^2/R_a. It appears to be the product of the mutual conductance and the voltage factor. I take it that is why it is called the power amplification, but I should like to hear more about that from this point of view. One index figure which would give a general indication of the performance of a valve is a very desirable thing. One might compare it with the single figure you give for the horse power of an engine. Looking at the figures which Mr. Turner has given us, I notice very wide discrepancies indeed between the values of μ^2/R_a given for different valves which one has not observed in practice to give such vastly different results in the amplification one gets; and I should like to know whether in fact this index figure he has given does give an indication of the relative performance of valves when they have a load in their anode circuits. He did not show us the effect of the anode load in straightening the curve, altering its slope, and in some cases turning a straight line characteristic into a loop when the load is reactive. There is just one point I should like to raise with regard to the method of testing crystals, and that is, that apparently, in order to get the low voltages, one finds it necessary to use a tapped inductance, and to assume that one can rely on the proportional voltage across the tapped piece being unaffected by the connecting up of the crystal across that piece. Is that so? A large ratio of diameter to length for the coil would help to keep the voltage ratio constant no doubt.

Mr. G. G. BLAKE: In the first place, I think the method that Mr. Turner suggested for classifying valves—putting the characteristic figures in the first column to indicate the different types of valves—is most useful. I have never seen it before, and I believe it is his own suggestion. If so, I think it might usefully be adopted. When one picks up the wireless papers and sees the different valves advertised, one is quite at a loss to know the characteristics of the many different valves, and with a notation such as that suggested we should know which valves were which. With regard to the measuring of the resistance of a coil composed of a tube filled with mercury, that method seems to me to be most interesting, and, I should say, very accurate. As to the Moullin voltmeter, do you know what difference there is in sensitivity as between that and the Lippmann capillary voltmeter, which was used by Roussel in France a little while ago? He carried out some measurements on the resistance of crystals and the rectified currents in crystal detector circuits, and he used a Lippmann capillary voltmeter.

Mr. J. H. REEVES, M.A.: There is one point on which I differ somewhat from Mr. Turner. He treated the capacity of a coil entirely as a shunt capacity which went in parallel with any tuning condenser. I was writing on the subject, and I pointed out that, suppose one began with a coil of, say, 20 gauge enamelled wire with turns touching, and then, keeping exactly the same pitch, wound with smaller and smaller gauge wire, one would have two effects. The self-capacity of that coil, or, as I prefer to call it, the distributive capacity, becomes very rapidly less at first, whereas the direct current resistance, and presumably the high frequency resistance, would increase somewhat slowly, and I had an idea that the actual efficiency of that coil as a receiving instrument ought to be improved. A 20 gauge enamelled wire coil with turns touching would not

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be so efficient a coil as one wound at precisely the same pitch, but with a somewhat smaller diameter wire. It came prominently before me this evening when Mr. Turner somewhat curtly dismissed the question of the distributed capacity of the coil as being merely a shunt capacity, and the whole tendency of the day seems to be to pay more and more attention to the elimination of the distributed capacity of the coil. As I said then, and I think still to-day, that distributed capacity has very much the same sort of effect on the coil as that of the oscillation in a submarine cable.

Mr. E. C. ATKINSON: Mr. Turner referred to the Willans method of measuring high frequency resistance, and it might be worth while to refer to a snag which I came across only the other day to be avoided in making measurements by that method. In an oscillator with two coils closely coupled, we are all familiar with the phenomenon of howling; that is to say, there are two high frequency currents, of slightly different frequency, flowing simultaneously in the circuits. If you uncouple to some extent the howling ceases, and apparently one of the high frequency oscillations has disappeared altogether. I notice, in attempting to measure resistance, that conditions may prevail in which the tuning of the circuit under test determines whether the other circuit oscillates with one or the other of two frequencies.

In this case the measure for the raised pitch of the heterodyne note is made at one frequency and that for the depressed note at another, the deduced value for the resistance being, of course, quite incorrect. I found those experiments exceedingly fascinating. So far I have only reached a stage at which I can consider results as being approximate. Perhaps my ear is not very critical, but I require a good deal of training to arrive at the exact point at which the pitch is highest, and it is dangerous to determine that point by swinging the condenser backwards and forwards unless you limit yourself as much as possible, because the curve slopes steeply on one side and gently on the other, and consequently, with a large swing the value deduced for the resistance will be too high.

Mr. P. R. COURSEY, B.Sc.: With regard to the self-capacity of coils as affecting the high frequency resistance of the coils, I think I am correct in saying that, although when the E.M.F. is induced into the coil, the C_0—the self-capacity—as has been stated, adds to the tuning condenser as far as tuning goes, yet if you make any attempt at measuring the effective resistance of that coil by anything connected externally to measure the current which must necessarily pass between the coil and the tuning condenser, then in both cases, whether the E.M.F. is induced into the coil or outside, the self-capacity will increase the effective resistance of the coil, because its effect is to shunt off some of the current that should otherwise go through the measuring instrument. I think, as a matter of fact, the formulæ work out the same in both cases for the increase in the effective resistance of the coil due to self-capacity.

Again, if the self-capacity of the coil is large, then it means that some of the current in the oscillating circuit which should be going through the tuning condenser—which has presumably an air dielectric, and consequently very small losses if reasonably constructed—will be passing through a distributed capacity in and around the coil and coil supports, which capacity may have in its circuit relatively poor dielectrics. In consequence, there may be a type of secondary increase of the resistance of the circuit, due to the self-capacity of the coil, and the fact that the electrostatic field of which that self-capacity is an expression is passing through poor dielectrics.

The Willans method of measuring high frequency resistance is very interesting, and is one on which I have done a little work recently. With the assistance of Mr. H. Andrewes, at the last informal meeting of the Society, I gave an experimental demonstration of how it could be used for measuring resistance. The accuracy of it can be considerably improved by using a double heterodyne or audio-frequency oscillator, but that, of course, introduces a lot of complications. I think also, the method we used then might overcome the difficulty Mr. Atkinson referred to. We used a 4-electrode valve oscillator instead of a 3-electrode one with a reaction coil. The result is that there are not two coupled circuits, and there is not the tendency for a frequency jump. I certainly agree with him that, as regards measuring capacities in general, the substitution methods are always the best, not only for radio-frequencies but for audio-frequencies as well, as even in the latter case it is quite possible to get considerable errors due to stray capacities.

There is one other point to which I should like to draw attention. Mr. Turner referred to the constancy of variable air condensers and probably the 2 per cent. he referred to is the average figure, but I have known aluminium-vane condensers which, when used in oscillating circuits, will give much greater accuracy than 2 per cent. over very long periods.

Mr. TURNER, replying to the discussion, said: Dr. Eccles raised a most interesting point in his reference to crystal efficiency tests in comparatively early days. I wish to goodness I had known about it, because I should have been spared many hard-working hours in evolving the methods described. He found efficiencies very much lower than mine—5 and 10 per cent.—and he was doubtful whether that was due to increased accuracy of measurement or improvement of crystals. I am inclined to think it is not due to either, but is due to the fact that measurements are now made on continuous waves. The efficiency of the crystals I have tested goes up rapidly with the amplitude. When applying a spark generator with heavily damped waves, a considerable amount of the input is of very low amplitude, and the efficiency of the crystal is pulled down by that fact, I think.

Mr. Child mentioned the neon tester, and asked whether there was any irregularity in the tubes. There is an interesting point there. If one is working in the evening, as most of this work has to be done, then with large condensers and high leaks (so that the nominal time of flash is of the order of several seconds) you sometimes get great irregularity. By daylight you do not, the whole secret being in the degree of ionisation in the gas within the neon

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lamp before the flash commences. In order to get extreme regularity, you must see that that is maintained constant. You can do it by experimenting in daylight or strong ultra-violet light, or by a chunk of radium, if you have it handy. (Laughter.)

As to the "omnibus" figure of merit for valves, I think the main difficulty there is a difficulty that runs through the whole of this testing, the fact that one wants different qualities for different circumstances of use. If one neglects that, one is liable to say that a certain component is a fine component, because it happens to suit the circuit you test it on. Many a casual test is merely a test of *tout ensemble*, of whether a component is matching the rest of the circuit, not whether it is itself good.

As to the question of proportional voltages in the crystal tester.

You have a main oscillator circuit, and you are shunting a portion of the coil by a resistance R (Fig. 20), and the question is whether a change in R changes the voltage ratio between E_1 and E_2. Well, of course it does, but if R is high enough in proportion to the reactance across which it is connected the change is not appreciable. The same question crops up in a simpler form in the potentiometer. In practice, for anything over about 1 000 ohms for R, in the circuit used, the correction is negligible as compared with the natural variability of the crystal.

With regard to the valve type numbers, that was an idea I was very proud of. In fact, I was so proud of it that I put it up to the Valve Makers'

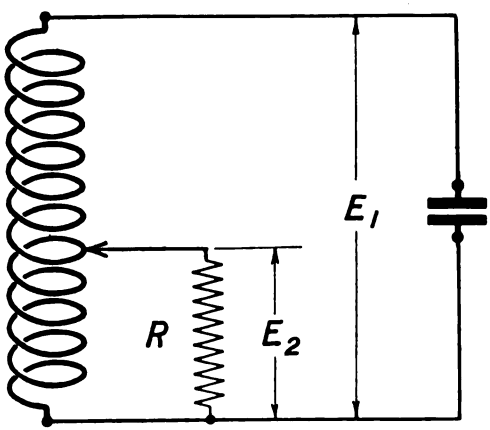

Fig. 20.

Association, and they replied in quite enthusiastic terms—for an association—"that it was worthy of very serious consideration." Apparently the consideration they have given it is so serious that nothing has transpired. After a month I wrote and said I hoped something might be transpiring, for that unless I heard it was transpiring pretty quickly I should go ahead and publish it, the implication being that the association were not (shall we say) progressive. Nothing transpired, and I did publish it, and the implication remains. (Laughter.)

As to the question of whether the Moullin voltmeter is affected by the D.C. component, the question can be avoided altogether by using for that job the other type of Moullin voltmeter, which, if you supply it with a mixed A.C. and D.C. voltage, will only measure the A.C.

The matter is, however, not serious for (see Fig. 21) the crystal is of a resistance of say, 20 000 ohms, and the load 10 000 ohms, so that there are 30 000 ohms in circuit. Now the Moullin is across the coil L, which has a D.C. resistance of only a few ohms, so that of the total D.C. voltage only 1/10 000 comes on to the voltmeter.

Both Mr. Reeves and Mr. Coursey raised the question of the efficiency of coils. Perhaps I was too hurried in speaking of self-capacity. The point I was trying to make is that the importance of self-capacity, as self-capacity, is somewhat overestimated. There is no doubt that self-capacity is a very serious disadvantage, for the reason quoted by Mr. Coursey, that the condenser formed by the distributive capacity is such a bad condenser. The point is that with every effort that you make in designing a coil to cut down the H.F. resistance due to dielectric losses also cuts down self-capacity. I was mentioning some coils I tried to wind for low losses. I wound them indifferently with 24 or 28 gauge wire. I am convinced that the use of heavy wire for coils is a complete mistake for high frequencies or low wave-lengths, because all the figures tend to show that for such work ohmic resistance and skin effect combined are unimportant compared with the dielectric losses, in the average design of coils. If you space your turns, say, 10 to the inch, use small wire so as to get more air between them. There must be, obviously, an optimum gauge of wire, which will depend on the design of the individual coil.

Mr. Atkinson described some of his troubles with the Willans method of resistance measurement. Undoubtedly, high frequency resistance measurement on accurate lines is quite a tricky job at first. It is necessary to make two measurements to get a high frequency resistance, one with and one without an added resistance. I usually make five or six, and as a rule I can work within .5 per cent. I have had no trouble with that change of oscillation in the Willans method. I am using an oscillator in which the coils are very closely coupled. The nearest point of the circuit to be measured is usually about six or seven inches away, and I have not had that change, but have found trouble in pitching on the exact adjustment at which the note is highest or lowest. It is simplest to use an extra audio-frequency oscillator and get slow countable beats.

As to the accuracy of condensers, the 2 per cent., as a matter of fact, was not my own estimate. It was the estimate given me by somebody at the National Physical Laboratory as the result of a lot of tests carried out there. The main difficulty with aluminium plates is that it is very hard to anneal them so that there is not a stress left in them. That stress comes out after a time and the plates warp. It is easier to flatten brass plates, but if you know a manufacturer who knows how to flatten aluminium, and is prepared to take the trouble there is nothing to choose between the two.

Mr. Fogarty: It is a great pleasure to me to have the opportunity of proposing a vote of thanks

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to Mr. Turner for his very interesting paper. I did not take part in the discussion because I think that, to a large extent, his lecture was clear, except for one or two points. These, however, came out in the discussion, and he has given satisfactory answers. I think we might take this paper as an example of the kind of which we want a great many more, because they are extremely useful to us, who are, for the most part, interested on the experimental side, and want to get down to measurements. The whole principle of science depends upon making measurements, and making them accurately, and our thanks are due in a particular measure to Mr. Turner.

The vote of thanks was accorded with acclamation.

The CHAIRMAN: There is suspended in the hall a list of candidates for membership, and of societies for affiliation. No comments have been raised, and I have to declare that 8 more members and 5 societies have been elected.

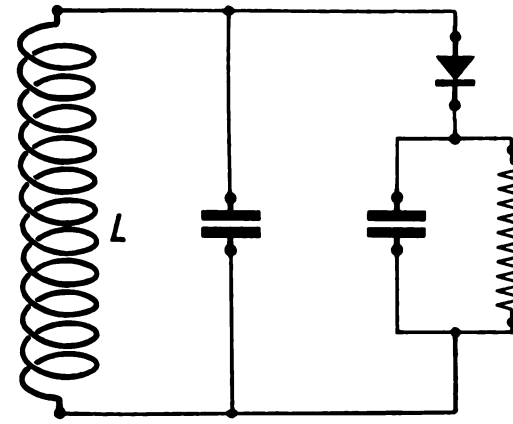


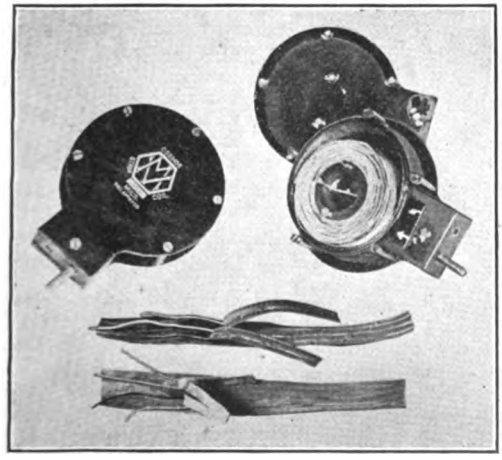
Fig. 21.

Two Low-Loss Tuning Coils. [R382·009

The "Cosmos."

METRO-VICK SUPPLIES CO. are the makers of a plug-in type of high efficiency and interesting construction.

In this coil use is made of a roll of paper in which a number of spaced wires are fixed, whose ends are linked through to form a continuous winding.



Above can be seen the general appearance (left) and the interior construction (right) of the "Cosmos." The wire "tape" is shown below.

The inductance, self-capacity and H.F. resistance were calculated using a wave-length of 377 metres.

In order to give some idea of the comparative value of the figures found, it was tested against another coil consisting of the same number of turns, 40, of a well-known make.

The inductance of the "Cosmos" was 92μH, while the other coil possessed 62μH. The self-capacity (including stray capacities of leads and our apparatus) amounted to 12$\mu\mu$F, as against 48$\mu\mu$F for the other coil.

It will be seen from this that the "Cosmos" has an extremely low self-capacity; the value of the stray capacities in our apparatus amounts to 9$\mu\mu$F, so that the net self-capacity of the "Cosmos" is only 3$\mu\mu$F, compared with 39$\mu\mu$F for the other coil.

The net resistances, measured at the same frequency, were found to be 4·5 and 3·910 for the "Cosmos" and the other coil respectively. In spite of this higher resistance, the "Cosmos" must be regarded as the better coil in view of its higher inductance.

The power-factor amounted to ·009 8 for the "Cosmos" and ·001 26 for the other.

The coils are supplied in a range marked 20-400, and cost 4s. 9d. to 9s. 9d.

The "Airmax."

Another coil lately tested by us is known as the "Airmax," made by Airmax, Ltd., of Sheffield. Its appearance is probably familiar to most readers.

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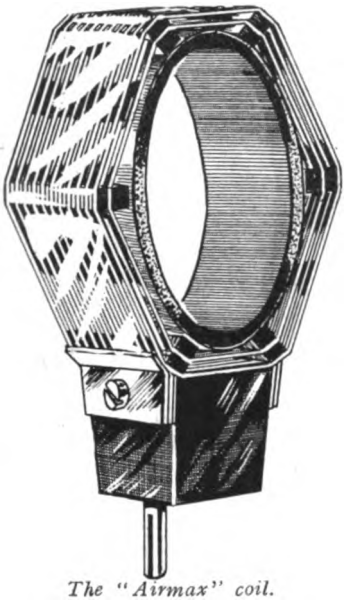


The "Airmax" coil.

It is wound with bare tinned copper wire, and spaced with insulating spacers. It is in fact a "Morecroft" coil, wound tightly and without external covering, or cheeks. It was tested after the same fashion as the "Cosmos."

The "Airmax" tested was a 50-turn coil, and it was compared with a similar size coil of a well-known make.

The inductance of the "Airmax" was found to be considerably greater owing to its larger diameter; it had a value of 203μH, against 131μH for the other coil.

The net self-capacities were approximately 21 and 31$\mu\mu$F (at 377 metres). The net H.F. resistances, measured at the same frequency, were 12·20O and 9·0O respectively.

Like the "Cosmos" it has a slightly higher resistance, but the power-factor was ·012 against ·014 for the other coil, thus proving the "Airmax" the better coil of the two.

These coils are made in nine sizes covering a wave-length range of 120-3 080 metres with a ·001μF condenser.

The prices are 5s. to 9s.

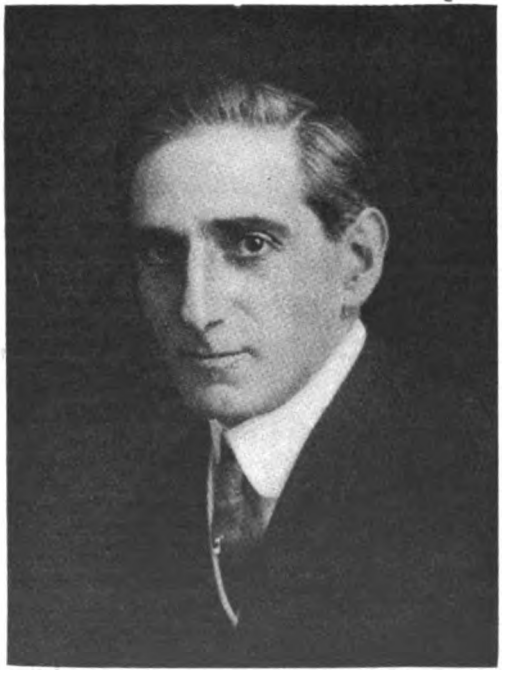
The Leicester Radio Society.

We are asked to announce that Joseph W. Pallett, the Hon. Secretary of the Leicester Radio and Scientific Society, has been forced to resign owing to ill-health. His position has been filled by Mr. A. E. Walker; all future communications therefore should be addressed to his residence—"Glen Burn," Ashleigh Road, Leicester.

Mr. Godfrey Isaacs. [R·097

THE death of Mr. Godfrey Isaacs, which occurred after a short illness at Virginia Water on April 17th, deprives the world of commercial wireless telegraphy of a great personality. For some time past his state of health had been a cause of anxiety to those closely connected with him, and it was for this reason that last November he resigned the position of managing director of the Marconi Co. With this company his name will always be coupled by those who watched the growth of wireless from infancy to sturdy youth, for it is largely due to his ability and acumen that the Company occupies its present position.

In 1910 he became associated with Marconi and later the control of the Marconi Company passed into his hands. Under him, its development proceeded apace.



Mr. Godfrey Isaacs, whose retirement, last November, was unfortunately too long delayed to save his health.

Thorough in all things, he had an unbounded zeal for work and did not always appreciate the fact that the structure must be strong enough to support the driving machinery. As a result, he worked without intermission and never spared himself. It has, indeed, been stated that for over 40 years he had not taken a holiday. His death at so early an age—he was only 59—will be deeply regretted by all who served under him, for he was popular alike with associates and subordinates.

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The Aerial-Earth System.

By E. Simeon. **[R320**

The results of experiments with various types of aerial and earth arrangement.

SOME years ago the writer erected a 45 ft. pole and hung from it a single wire aerial with three shell-type insulators at each point of suspension. It was about 60 ft. long and had about 40 ft. of down-lead, the receiver being on the ground floor, and the usual waterpipe earth being employed.

The aerial system gave what were thought to be satisfactory results, and no further trouble was taken over it for a time. As it stood, it was probably at least as good as the average receiving aerial; yet by various small improvements, and without increasing its height or length, the received strength on a standard set was subsequently increased to about four times its original value.

For the comparison of results given by various arrangements, a leaky grid-condenser detector without reaction was used. An "R" valve was employed on 90 volts, with which it gave 40 per cent. greater strength than with 60 volts. The efficiency of any given system was taken to be indicated by the maximum drop in anode current caused when passing through resonance. The drop caused by 2LO was found to be very constant, rarely altering by 5 per cent.

This method of testing aerial efficiency is more reliable than by measuring aerial current given by a constant input transmitter, since false impressions might be caused through increase in capacity, etc.

No reliance could be placed on judging strength by telephone, it being found difficult with music to notice any change in volume when the current drop was altered by 30 per cent., though with a pure note it was much easier.

The first thing done was to get the receiver reasonably efficient, so that measurable readings could be obtained. The circuit which had been used for 360 metres consisted of an 80-turn honeycomb coil with a ·001mF series condenser, about ·000 1mF being actually employed. When a valve was used as detector, this arrangement was found to be about the best, the drop reading about 150 microamps.

As a matter of interest, this tuning circuit was tested against others when a crystal was used as rectifier, and totally different results obtained. Here the current delivered was only 15 microamps, using the series circuit. This astonishingly small current gave a telephone strength just lost at a few inches from the ears. Probably most crystal users have under 10 microamps of D.C. flowing.

When, however, a 45-turn coil was substituted with a small parallel capacity, a current of 40 microamps was delivered, and finally, by the use of the 80-turn coil as secondary with loose coupling (45° apart) an increase to 54 was obtained. No improvement by using a secondary was obtained if more than .000 2mF was allowed across the coil. Tuning was also very considerably sharpened. Of course, we all know that an improvement can be obtained by using a secondary, yet how many B.C.L.'s use one?

Coming back to the valve detector, alterations in tuning coils were tried, but at this stage did not give substantial improvement, due to large losses elsewhere. That there were losses was obvious from the fact that a non-inductive resistance of 20 ohms could be inserted in the aerial lead without any appreciable drop in strength!

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For raising the aerial wire, a stranded-steel, ex-Government signalling cable, being handy at the time, had been used. The cable was also used to fasten together the groups of insulators at either end. It was thought that a certain amount of capacity leakage might be taking place through the porcelain, and a short length of whipcord was substituted for the cable. This resulted in a slight increase—about 15 per cent.—and noticeably sharpened tuning.

It was not thought safe, however, to leave the cord to withstand the weather, as its breaking would mean that the pole would have to be lowered in order to obtain the end again. The cable was attached to a weight of a pound or two at the point where it joined the cord, so that in the event of the latter breaking, the weight would then bring down the end over the pulley on paying out cable from below.

The copper wire itself was renewed and the insulators cleaned after two years of London smoke. No noticeable change occurred, however, showing it to be unnecessary continually to overhaul the aerial. The oxide which soon forms on the wire is practically an insulator, so that it does not affect the resistance.

The next thing tried was to substitute a twin wire aerial. To lessen sagging, the 7 ft. spreaders were made of small section ash ½ in. square. With this aerial, a drop of 220 microamps was obtained, an increase of over 25 per cent. A large increase in aerial capacity was noted, a 50-coil now being used with about the same series capacity. This is, of course, an advantage when higher wave-lengths are to be reached, though for getting down to low wave-lengths it would be better to keep to the single wire. Some tests were next made on the earth connection. It is perhaps not always ealised that a connection to a water main—giving a D.C. earth of utterly negligible resistance —is often unsatisfactory for short-wave work. Suppose connection to be made directly to the main itself, running away underground for an indefinite distance. In any case, a wave of, say, 360 metres can only possibly travel 180 metres along it during a half-cycle, so that for this or lower wave-lengths the rest of the pipe may be absolutely neglected. Obviously, the shorter the earth lead the better, since the effective buried length is proportionately greater.

It is, therefore apparent that a water-main connection to earth has a very definite H.F. resistance, which becomes serious with shorter wave-lengths. On the other hand, it is possible to have a good H.F. earth connection, yet one with a high D.C. resistance; for instance, a buried enamelled iron plate, where the glaze would act as a dielectric between the plate and the surrounding soil.

It was found that to get a reasonably low-resistance earth connection by means of a buried iron plate, a very large surface must be offered before a better connection

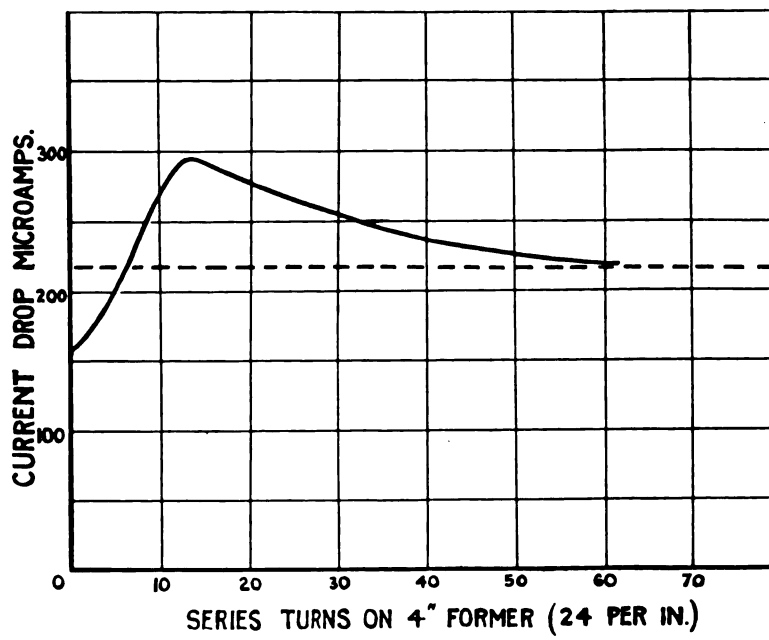

Fig. 1. *Showing the effect of using two earths in parallel.*

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can be made than a water-main will give at 360 metres. An iron plate was buried in damp soil, with a total contact area of 34 sq. ft., and this, when used with the aerial, gave about 60 per cent. of the strength from the water-pipe earth. This roughly indicated, therefore, that the latter was acting as if it were a length of only about 75 metres of pipe, all concentrated at the foot of the aerial.

In all probability, in a case where a long earth lead would have to be employed to reach a water-pipe, a similar plate would give better results.

The next thing which obviously suggested itself was to use both earths in parallel. This led to some curious results, caused by the fact that the two earth leads were of different lengths. It was found that with the water-main earth the signal was tuned in some 10 to 15° lower, showing the latter lead to have an appreciable inductance.

The curve of Fig. 1 shows the effect of using the two earths in parallel. The dotted line shows the current drop with the water-pipe earth alone. On joining the plate earth to it, the output dropped by about 30 per cent. When, however, a small inductance was placed in series with the lead to the plate, a well-defined optimum point was found, at which the resistance was considerably below that of either earth singly. The insertion of this coil had only a very slight effect on the wave-length.

It is not thought that this inductance would need changing on other wave-lengths, though it was not possible for the writer to test this point, no other station being close enough to give measurable readings.

In the writer's case, too, it was not possible to have a counterpoise permanently in use, owing to the objections of the domestic authorities. It was, however, tried as an experiment—to see whether it was worth while bringing pressure on the latter—and interesting results were obtained.

A three-wire counterpoise was employed, about four-fifths the length of the aerial and 7 ft. above ground level. The wires were parallel, and spaced 4 ft. apart. With this an increase over the combined earths of 30 per cent. was obtained—the drop now measuring 385 microamps. With the two outer wires only 375 microamps, and with the centre one only (the others being cut away) 365 microamps were indicated. It does not, therefore, seem probable that much would be gained by the use of more than three wires.

Little difference was shown whether the wires were arranged parallel or fan-fashion, or whether they were slightly longer or shorter than the aerial. The counterpoise system required considerably more series-capacity to tune in on the same coil, almost .000 1mF extra being needed.

Finally, some trials with various coils were made. A 5 in. diameter solenoid, with a skeleton former and wound with 16 S.W.G. wire, used in place of the duolateral coil, increased the output by another 40 per cent. —the final reading being 540 microamps. The latter coil was wound with 26 D.C.C., and might be taken as a typical one of its kind. It was held together with a minimum of wax, though for this purpose celluloid would probably be more suitable, both from the point of view of distributed capacity and mechanical strength. The coil could be soaked in a solution of celluloid in amyl-acetate, and then gently dried off.

Some further tests were carried out on the tuning condenser, but they showed that even with one of the cheapest makes, results were substantially the same as those given by a first-class instrument. This is, of course, a rough comparison of efficiency only, and does not mean that a well-made condenser would not be preferable for constancy and reliability.

As a matter of interest, the effect of inserting a series resistance in the aerial lead was tried again, and 5 ohms caused a large enough drop in strength to be detected with the phones (some 30 per cent.), showing the ohmic resistance now to have been reduced to a reasonable figure. When using such an aerial, the effects of oscillation will be rendered more serious, necessitating more care when searching.

In conclusion, it is thought that many amateurs might profitably spend a little time on that part of their apparatus on the outdoor side of the aerial and earth terminals. It is of little use, say, to use thick wire for coil winding, if the earth used consists of a 3-ft. iron rod driven into the ground.

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More Valves Tested.

With a Note on our Methods. [R333·009

JUST lately one or two cases have occurred in which our values for the R_a and μ (anode impedance and voltage amplification) of valves have not agreed with those of the makers, and questions have been raised as to which was correct.

It seems advisable, therefore, that we should give definite information on the way in which these values are found. First, we must emphasise the fact that, in spite of every effort on the manufacturers' part, sister valves do differ somewhat between themselves, and we can never state definitely that the sample tested by us is actually an average one. Secondly, as we will show, there are possibilities of quite wide divergence in finding R_a and μ, even with the same valve.

We will start by describing just how we proceed. First, the filament is lit, and adjusted to a definite voltage. Then, with the grid connected direct to filament negative, the anode voltage is gradually increased from 0 to 200, or saturation, whichever occurs first, and the anode current noted at various voltages. The corresponding curve is then drawn. If the curve shows a well-defined straight part, we find ΔI_a and ΔE_a across the straight, as shown in Fig. 1, p. 487, and from them get R_a by simple division. In the valve shown on that page this is approximately 23 000 ohms.

Next, we apply one cell—say, 1.4 volts, in any case we measure it carefully—of negative bias, and adjust the anode volts until we get an anode current well on the straight part of the curve—we used 2.5mA in this case. Then, without touching the anode volts, we make the grid volts in succession 2.8 and 0. In this case the resulting anode currents were 1.9 and 3.1mA, making ΔI_a .6, for ΔE_g=1.4. This, by division, gives G_m $\left(\text{mutual conductivity}; =\frac{\Delta I_a}{\Delta E_g}\right)$ equal to $\frac{.43}{1000}$

Now to find μ, we have only to multiply G_m by R_a—

$$G_m \times R_a = \frac{\Delta I_a}{\Delta E_g} \times \frac{\Delta E_a}{\Delta I_a} = \frac{\Delta E_a}{\Delta E_g}$$

and in this case we find 9.86.

It will be noted that, with the same change produced by a given grid voltage, *i.e.*, the same G_m, a lower anode impedance gives a lower μ, which is why in many cases the μ of a valve falls off at higher filament volts (note the S.P.18 valve, reported below). Now suppose, however, that instead of measuring R_a in the way we suggest, over the straight part of the curve, we were to measure it somewhere about *B* in Fig. 2, p. 488, without actually drawing a curve, we should find that to get a ΔI_a of .5mA (1 — .5) needed a ΔE_a of 17V (53 — 36), giving R_a= 34 000. If the mutual conductivity came to $\frac{.43}{1\,000}$ as before, we should find μ=14.6.

Now in one particular case we were testing a valve of rather high μ, and the straight part of the curve centred about a value of 200 anode volts. We accordingly gave R_a and μ for this value. The makers had done the very thing shown above. They had measured R_a at about 100 volts, and the μ they got was much larger than our value.

They made the excellent point that the general public would use about 100 volts, so that their values were those that would obtain in practice. Our reply is that anyone so unwise as to use a valve for amplification while working on a curved part of its characteristic would not appreciate the meaning of R_a or μ at all: and that our values were for the only portion of the valve characteristic at which it *ought* to be used for amplification.

A somewhat similar difficulty arises in the case of certain valves of which the characteristic tends to get steeper and steeper all the time. This is especially likely to be the case if there are signs of softness. In this case one can only measure at some reasonable value, and state at what value. In the absence of any such details, it can be taken that the values given by us are those measured on the straight portion of the curve.

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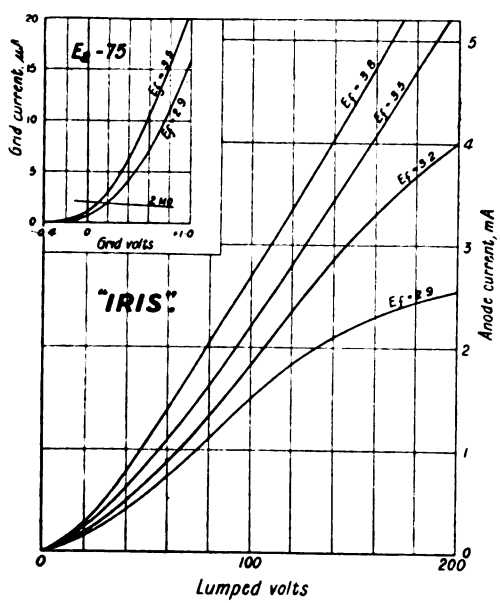
Iris ·06.

This is a French valve of the 60 milliamp type, supplied by Messrs. Anglo-Franconia, Ltd., Baltic House, 27, Leadenhall Street, E.C.3. Like most French valves, it is designed for a rather higher magnification than is the common practice in England: as is seen from our table,

Fil. Volts. E_f	Fil. Cur. I_f	Sat. Plate Cur. I_s	Anode Imped-ance. R_a	Voltage Ampli. μ	Power Ampli. P $\left(=\frac{1\,000\mu^2}{R_a}\right)$	Filament Efficiency F $\left(=\frac{I_s}{\text{Watts.}}\right)$
2.9	.059	3	55 000	12	2.6	17.3
3.2	.064	6	42 000	12.5	3.7	29
3.5	.069	10	35 000	13	4.8	41
3.8	.075	15	28 000	13	5.6	53

the μ varies between 12 and 13, and it is notable that it actually increases with the filament heat. Another point it shares with most French valves of this type is that it is designed for a distinctly higher filament voltage than the English 60 milliamp valve. It is in fact a ·406 rather than a ·306 valve. The curve sheet for this valve shows that while there are no points of exceptional interest,



the valve shows every prospect of being thoroughly efficient, and it should be noted that it is sold at the comparatively low price of 9s.

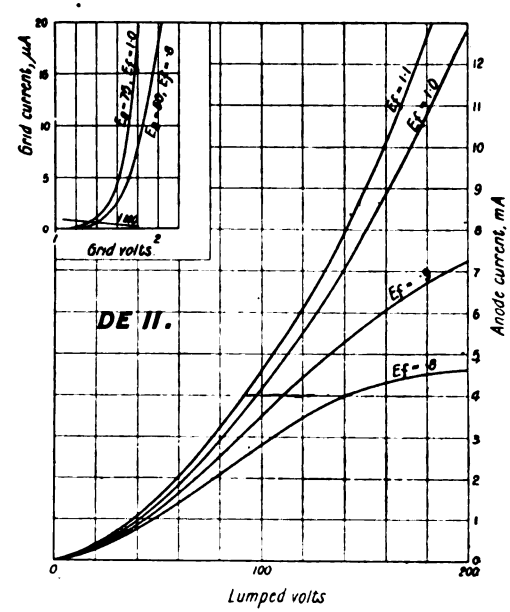
Two Metro-Vick Valves.

Two interesting valves have been received for test from Messrs. Metro-Vick Supplies, Ltd., 3, Central Buildings, Westminster, S.W.1, these being the D.E.11 and the S.P.18. The D.E.11 is what we ourselves should call the 125 type, using a coated filament and designed to be run on a single large dry cell. In common with most valves using oxide-coated filaments, there are traces of softness: it will be seen that at the full rated voltage of 1.0 or more on the filament it is impossible to find a saturation current, as ionisation takes place. None the less, the valve possesses excellent qualities, showing an average magnification with a low anode impedance.

Fil. Volts. E_f	Fil. Cur. I_f	Sat. Plate Cur. I_s	Anode Imped-ance. R_a	Voltage Ampli. μ	Power Ampli. P $\left(=\frac{1\,000\mu^2}{R_a}\right)$	Filament Efficiency. F $\left(=\frac{I_s}{\text{Watts.}}\right)$
.8	.20	5	31 000	8	2.1	30
.9	.22	10	25 000	7.5	2.2	50
1.0	.235	—	15 500*	6	2.1	—
1.1	.25	—	14 000*	6	2.8	—

* At 120V.

An interesting point arises in connection with the grid current curve. It will be seen from our illustration that there is no trace of grid current until a positive voltage of slightly more than 1 volt is applied to the grid. From this point onwards the rise in grid current is very rapid. It would thus appear that the valve has a distinct field for use



in the early stages of a note magnifier without grid bias, provided that it is not subjected to an input of more than 2 volts grid swing. At the same time, the very rapid rise of grid current once it has started indicates that the valve should possess useful properties as a detector.

An even more interesting valve from the same house is the S.P.18, in which we are informed the letters S.P. stand for "short path" and the 18 designates the filament voltage. We should refer to it as a 235 valve. This valve also uses an

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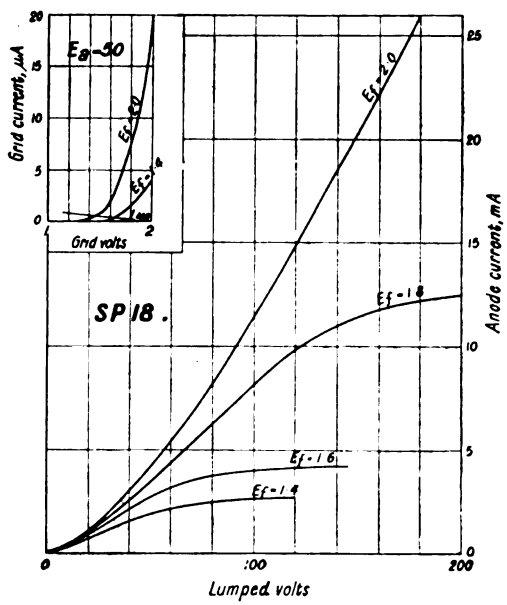
oxide filament, but is most remarkable for the design of the electrodes. The ruling idea of the construction has been to get the filament, grid,

Fil. Volts. E_f	Fil. Cur. I_f	Sat. Plate Cur. I_s	Anode Impedance. R_a	Voltage Ampli. μ	Power Ampli. P $\left(=\frac{1\,000\mu^2}{R_a}\right)$	Filament Efficiency. F $\left(=\frac{I_s}{\text{Watts.}}\right)$
1.4	.25	3	40 000	12	3.6	5.4
1.6	.27	6.5	25 000	11.3	5.1	9.3
1.8	.30	15	12 500	7.3	4.3	28.0
2.0	.33	—	6 200	3.7	2.4	—

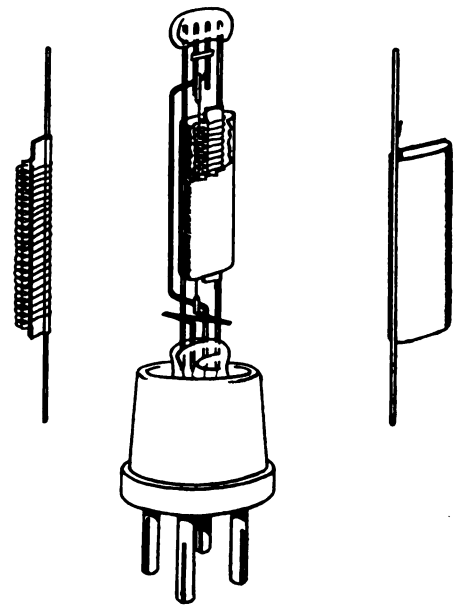
and anode very close together in order to obtain a very low anode impedance, while maintaining the magnification large—which is, of course, the idea behind the construction of many modern power valves employing flattened plate and grid. In the S.P.18 the grid is cylindrical, employing the usual helical winding, but in order to provide a solid support the grid is extended as shown in our sketch. It must be borne in mind, however, that the extension is merely a support, not part of the working grid. Its construction has involved a rather peculiar design of anode, which at first sight resembles that of the flattened type already mentioned. This, however, is not actually the case, for the working portion of the anode is simply



that part surrounding the working portion of the grid, the remainder of the anode merely being made of this particular shape as a convenient practical construction.

On test the valve showed up extremely well, although here again there were signs of softening at full grid filament heat. The value of 15 milliamps for the saturation current at 1.8 volts was in fact somewhat indefinite, as a further increase in the voltage applied tended to cause ionisation and a rush of emission.

It is obvious from the values given for anode impedance that the design has been completely successful from this point of view, the impedance falling to a figure as low as 6 200 volts on the filament. The mutual conductivity, however, did



The interior construction of the S.P.18 valve.

not increase in the same proportion, with the result that the value of μ falls considerably. Bearing in mind that both the anode impedance and the voltage amplification are involved in arriving at the best figure of power amplification, we find that the valve is most efficient from this point of view at quite a low filament heat. It would appear from the values obtained, which were confirmed by actual test, that the valve should have great scope in the early stages of a note magnifier, for, as in the D.E.11, grid current does not start until more than one volt positive has been applied to the grid. It must be noted that there is sufficient output to handle a loud-speaker at full filament heat, but under these conditions the magnification is not so high. It is an important point that practically distortionless amplification, even for loud-speaker work, can be got with not more than 100 volts or so on the anode, which is an exceptionally useful property. The grid current curves show exceptionally efficient rectification provided that the filament is kept fairly bright. The prices of the D.E.11 and S.P.18 are 21s. and 18s. respectively.

The "Six-Sixty."

We have seen some interesting claims made for the "Six-Sixty" valve employing a special filament, which we believe is of molybdenum wire.

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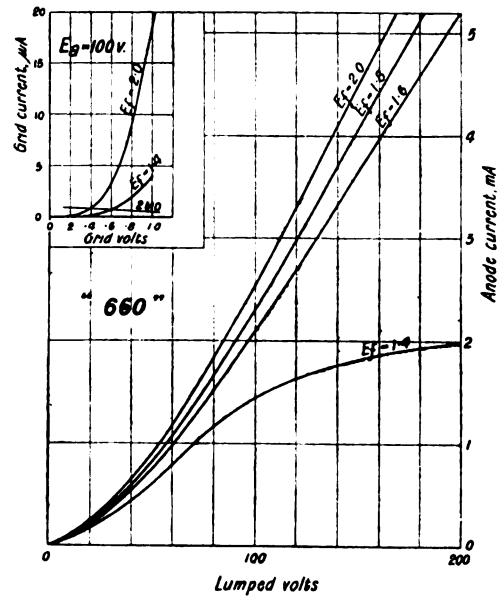
In view of the rating of the valve (1.8 volt, .3 amp) it appears probable that the actual emission is due to the filament being thoriated, in which case, of course, the substitution of molybdenum for tungsten as a filament material would not be extremely important from this point of view. This opinion appears to be justified by the results of actual test, for as regards performance the valve behaves in a manner essentially similar to that of the ordinary thoriated type, although it must be said that the results were in many ways exceptionally good.

Fil. Volts. E_f	Fil. Cur. I_f	Sat. Plate Cur. I_s	Anode Impedance. R_a	Voltage Ampli. μ	Power Ampli. P $\left(=\frac{1\,000\mu^2}{R_a}\right)$	Filament Efficiency. F $\left(=\frac{I_s}{\text{Watts.}}\right)$
1.4	.33	2.5	50 000	11	2.4	5.8
1.6	.36	6.5	36 000	11	3.2	11.4
1.8	.385	10	31 000	11	4.0	14.5
2.0	.42	15	28 000	14	7.3	18

In appearance the valve is very neat, the bulb being quite small and cylindrical, and the cap being of some insulating material mottled in red and black. The table and curves reproduced here show its performance in a smaller compass than an extended description could do. A particularly notable point is the rather high magnification, which is obtained with a comparatively low anode impedance. The magnification also is maintained at comparatively high filament heats, owing to a considerable increase in the mutual conductivity. This results in an excellent value for the power amplification at full filament heat, although we still do not think the output quite sufficient for the satisfactory operation of a loud-speaker. An examination of the curves shows that they have the useful feature of straightening out at comparatively low voltages, thus ensuring distortionless amplification without the use of large batteries. The grid current curves are normal, but, as will be noted, the increase in



grid current in increasing filament heat is very rapid, indicating that the valve would probably function most satisfactorily as a detector if the filament is maintained fairly bright. The valve is supplied by Messrs. The Electron Co., Ltd., Triumph House, 189, Regent Street, W.1, at the price of 18s.

USES OF THE SUPERHET.

Owing to continual interference from an uncertain source, members of the Plate and Grid Club, of Stamford, Conn., U.S.A., an organisation of listeners and amateurs of the American Radio Relay League, decided to take the matter into their own hands. With the co-operation of the *Stamford Sentinel*, it was found that trouble was being caused by the local lighting company's high power lines. With the aid of an eight-valve superheterodyne set and a frame aerial, mounted in a car, the interference was found to be coming from several leaks in the cables.

It was also observed that the decrease in signal strength was not so pronounced while the car was travelling parallel to the wires as it was when the car passed through side streets at right angles to them.

THE PROGRESS OF WIRELESS IN RUSSIA.

Strange and contradictory reports are constantly received from Russia with regard to the progress being made in wireless telephony and telegraphy in that country. There is, however, some information that may be relied upon. One of Russia's finest engineers, M. A. Boutsh-Brujewitsh, is at present at work at Nijni-Novgorod on a water-cooled valve, which he hopes will furnish a power of 100 kilowatts. The valve will be constructed in the same manner as one previously made by the same engineer, and which gave a power of 81kw.

The laboratory at Nijni-Novgorod was officially founded by the Soviet Government for their own use in October, 1918. It is now under the Directorship of Professor Lebedinsky, who has just returned there after a tour of Eastern Europe.

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More about Errors in Measurement.

By P. K. Turner. **[R800:519·8**

A simplified treatment of the Method of Least Squares, by which experimental results are treated to find the most accurate possible values

IN a short article on "Errors in Measurement" (E.W. & W.E., March, 1925), the author dealt with the best value and probable error of a directly observed quantity, and also showed the graphical construction for less simple cases, where we are trying to find one quantity by measuring others.

It was then stated that the most satisfactory method of dealing with such work is the "Method of Least Squares," and the author tried to get out of describing this. However, quite a surprising number of readers have asked for it, so. . . . . .

The problem is this, to give a typical example: We wish to find the self-capacity and true inductance of a coil, by measuring the wave-length given by the coil with various condensers across it. (This is the same example as already dealt with.) We know that the quantities are connected by this equation :—

$$L\,(C + C_s) = \frac{\lambda^2}{3\,550} \qquad .. \quad (1)$$

Where L is the inductance, C the added capacity, C_s the self-capacity, and λ the wave-length.

Now this equation can be made simpler in appearance as follows. Obviously,

$$LC + LC_s = \frac{\lambda^2}{3\,550} \qquad .. \quad .. \quad (2)$$

Now, of these letters, L represents a constant unknown quantity (call it x), C is a varying known quantity (call it a), LC_s is a constant unknown (call it y), and $\frac{\lambda^2}{3\,550}$ is a varying known (call it m).

The equation thus becomes—

$$ax + y = m \qquad .. \quad .. \quad (3)$$

where x and y are to be found.

Obviously we cannot find them from one equation, but we can from two. Thus: If for one observation $a=2$, $m=8$, and for another $a=3$, $m=10$, we have

$$\left.\begin{aligned} 2x+y&=8 \\ 3x+y&=10 \end{aligned}\right\} \qquad .. \quad .. \quad (4)$$

from which any schoolboy will give us $x=2$, $y=4$.

Now suppose we take three observations, the third being $a=1$, $m=7$.

We have

$$\begin{aligned} x+y&=7 \qquad .. \quad .. \quad (5) \\ 2x+y&=8 \qquad .. \quad .. \quad (6) \\ 3x+y&=10 \qquad .. \quad .. \quad (7) \end{aligned}$$

and now we run up against the distressing fact that no values of x and y can be found which will satisfy all three equations. In this case, (5) and (6) give $x=1$, $y=6$; (5) and (7) give $x=1\frac{1}{2}$, $y=5\frac{1}{2}$, and, as before, (6) and (7) give $x=2$, $y=4$. The reason, of course, is that the quantities a and m have not been observed with absolute accuracy; and the problem is: What values of x and y are the nearest we can find to their unknown true values; and what is the probable error in our estimate?

Various methods might be suggested, such as taking the equations two by two, solving them, and averaging the results, etc., etc. But the mathematicians have shown us what is by far the best.

If we re-write the three equation as

$$\left.\begin{aligned} x+y-7&=0 \\ 2x+y-8&=0 \\ 3x+y-10&=0 \end{aligned}\right\} \qquad .. \quad .. \quad (8)$$

and then substitute some definite values of x and y in them, they will not all reduce to zero. Thus, taking $x=2$, $y=4$

$$\left.\begin{aligned} 2+4-7&=-1 \\ 4+4-8&=0 \\ 6+4-10&=0 \end{aligned}\right\} \qquad .. \quad .. \quad (9)$$

Again, if we put $x=1$, $y=6$,

$$\left.\begin{aligned} 1+6-7&=0 \\ 2+6-8&=0 \\ 3+6-10&=-1 \end{aligned}\right\} \qquad .. \quad (10)$$

Note the figures on the right of these equations (0, 0, and —1 in (10)). The mathematicians tell us that if we square all these, and add them together, then the best values of x and y are those that give the smallest sum.

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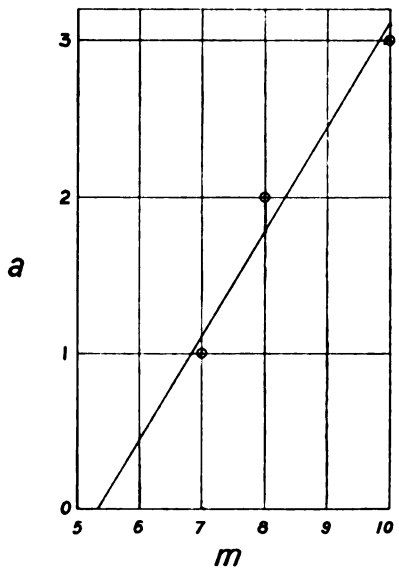
Now, how do we find these values? The method, carried out in a general way, is complicated and laborious. But by taking only a restricted class of equations we can simplify it enormously, and the author now proposes to give definite instructions applicable to most cases that readers will come across, without going at all into principles.

The first thing is to write down the governing equation. In the case quoted above (self-capacity and true inductance)

$$L(C + C_s) = \frac{\lambda^2}{3\,550} \quad .. \quad .. \quad (11)$$

Then convert this into the standard form

$$a'x + y = m'$$



The three readings of Example 1, with the "best" straight line among them.

where $a'x$ is a compound term containing a varying known term a' and a fixed unknown one x,

y is a fixed unknown term,

m' is a varying known term.

Thus we can set out (11) as

$$LC + LC_s = \frac{\lambda^2}{3\,550} \quad .. \quad .. \quad (12)$$

Where LC corresponds to $a'x$, a' being C' and x being L;

LC_s corresponds to y

and $\frac{\lambda^2}{3550}$ corresponds to m',

or we can change (11) to

$$C + C_s = \frac{\lambda^2}{3\,550}\,\frac{1}{L} \quad .. \quad .. \quad (13)$$

here C corresponds to m'

C_s corresponds to y,

$\frac{\lambda^2}{3\,550}$ corresponds to a'

and $\frac{1}{L}$ corresponds to x

In this latter case the result is

$$m' + y = a'x \quad .. \quad .. \quad (14)$$

$$\text{or } a'x - y = m' \quad .. \quad .. \quad (15)$$

so that we will say $y = -C$.

If one of the two known quantities can be more accurately observed or measured than the other, make that one m'.

If the equation cannot be thrown into this general form, the following procedure is not correct. But usually there is little difficulty.

In the following procedure, certain items are concerned with the sum "s." These calculations are not *necessary* to get the result; they are *checks*, to prove correctness. Having had considerable experience of such work, the author strongly advises that they should be used.

First, set out Table I., fill it in, and do the arithmetic indicated. (Note, n is the number of observations.)

TABLE I.

Observation No.	a'	m'
1	.....	.....
2	.....	.....
3	.....	.....
.	.	.
.	.	.
.	.	.
n	.....	.....
	$n = ..$) _____ = Sum.	$n = ..$) _____ = Sum
	$a_0 =$ _____ = Av.	$m_0 =$ _____ = Av.

It will be seen that we are simply finding average values for a' and m', which we call a_0 and m_0.

Next we have the largest job of all—to make out and fill in Table II. This introduces us to several new quantities, of which the first three are a, m, and s, given by

$$a = a' - a_0 \quad .. \quad .. \quad \text{I.}$$

$$m = m' - m_0 \quad .. \quad .. \quad \text{II.}$$

$$s = a + m + 1 \quad .. \quad .. \quad \text{III.}$$

The values for a, m, and s for each observation are set out in their respective columns, and the first check on the accuracy of working

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TABLE II.

	$a = a' - a_0$			$m = m' - m_0$		$s = a + m + 1$		
Observation.	a	m	s	a^2	m^2	am	as	ms
1	.....	.....	.....	.....	.....	.....	.....	.....
2	.....	.....	.....	.....	.....	.....	.....	.....
3	.....	.....	.....	.....	.....	.....	.....	.....
.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.
n	.	.	.	.	.	.	.	.
Sums.	....	....	....	.....	.....	.....	.....	.....
	O	O	.....$=n$	A	B	C	P	Q

is that the sums of the a and m columns shall be zero, and that of the s column n:—

FIRST CHECKS: $\Sigma a = \Sigma m = O$ .. .. IV.

$\Sigma s = n$ .. .. V.

Now comes the task of filling the other columns, the squares and products being got from tables, logs, or slide-rule (but see below as to slide-rule working).

SECOND CHECKS: $A + C = P$ .. .. VI.

$B + C = Q$ .. .. VII.

Then $x = \frac{C}{A}$ .. .. ..VIII.

$y = m_0 - a_0 x$ .. .. .. IX.

give the best values for x and y.

Next, to find the probable errors.

Find D, from the equation

$D = B - xC$ .. .. X.

and R, from

$R = Q - xP$ XI

THIRD CHECK: $D = R$ .. .. .. XII.

Note here that D should be small, and it is usual to find that B and xC are large numbers nearly equal. It would, for example, be by no means unusual to find $B=100$, $xC=99.99$, whence $D=.01$.

Hence, a very small percentage error in calculating B, x, or C might give a very large percentage error in D. If, for example, we got $xC=99.98$, this is an error of 1 part in 10 000 approximately. But it would give $D=\cdot 02$, an error of 100 per cent! Hence, if D is wanted accurately, it is advisable to go to some trouble with Table II. Five-figure, or if not too much labour, seven-figure logs should be used.

Having found D, we have, calling r_x the probable error of x,

$$r_x = \sqrt{\frac{\cdot 455 D}{(n-2)A}} \quad .. \quad \text{XIII.}$$

and

$$r_y = a_0 \times r_x \quad .. \quad .. \quad \text{XIV.}$$

As a last check (though it is seldom that one is enthusiastic enough to carry it out), make out and fill in Table III.

TABLE III.

Observation.	a'	$a'x$	$a'x+y$	$v = a'x+y-m'$	v^2
1	....	....	.....	.....	.....
2	....	....	.....	.....	.....
.	.	.	.	.	.
.	.	.	.	.	.
.	.	.	.	.	.
n					
			Sums	o	$D=\ldots=R$

As a first example, in easy figures, it is proposed to take that already given—the three equations

$$x+y=7$$
$$2x+y=8$$
$$3x+y=10$$

(*To be concluded.*)

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Long-Distance Work.

By Hugh N. Ryan (5BV). [R545·009·2

SINCE last month's report was written, interest has centred chiefly around the development of much shorter waves than those lately employed for DX work. Most of the winter's work was done on waves between 70 and 100 metres, and these were by far the most useful we had ever used.

More recently, however, considerable attention has been given by a number of well-known experimenters to shorter waves, chiefly those around 40 and 20 metres.

Most of the 40-metre work has been conducted in America, and the results, though interesting, are not startling. A wave-length of 40 metres apparently behaves very much as one of 90 metres, except that it possibly travels rather farther, in bad weather conditions, than does the higher wave.

The 20-metre wave, however, on which considerable work has been done on both sides of the Atlantic, has been found to behave in a way quite its own. Its most apparent—and to us all-important—property is that it travels very much better by day than by night.

All the longer waves, from the 1 000 metres with which we started many years ago, to the 80 metres which we now use most generally, are only useful for long distances at night. Each of the successively-shorter waves which we have used have extended the period during which we could work America, until now, on 80-90 metres, we can work under good conditions from about 10.30 p.m. to 8.30 a.m.

The 20-metre wave does much to fill in the "dead" gap, as it enables us, at this time of the year, at any rate, to work across the Atlantic from about 9 or 10 a.m. until about 7 p.m. These figures are not exact, but indicate roughly the large portion of the day during which the short wave is useful. With the fall of darkness the signals fade away, just as longer wave signals fade out in the morning. The only other notable characteristics of 20-metre signals are the violent fading to which they are subject and the very unusual distribution of signal strength over various distances.

Signals on this wave are audible up to about 25 miles from the transmitting station, and then absolutely inaudible until about 400 miles from it. At distances greater than 400 miles a fairly steady strength is found, up to considerable distances. (About 7 000 miles as observed so far.) The most obvious, and probably correct, explanation is that the direct waves from the transmitting aerial are absorbed before they have travelled far (in this case about 25 miles), as would be expected of very short waves; and the reflected waves (from the ionised layer) do not become effective until about 400 miles from the aerial. There are two possible explanations of this last fact, as will be readily apparent, and the whole question should provide an extremely-interesting line of discussion and investigation.

The leading station in this work on the American side is NKF, a naval station which has for a long time co-operated with American and European amateurs in short-wave investigations. He is using 1.5 kilowatts on 20 metres, and his signals are very strong at all times of the day, both here and in France.

The pioneer American amateur on these waves is John L. Reinartz, 1XAM, an old friend on the longer waves. Other Americans often heard are 1CMP and 1CKP, both also old friends.

Most of the work on this side has been done by 5LF, who has worked NKF daily for long periods. 2SH and 2KF have worked 1CCX and 1CMP respectively.

The only Frenchman at present on 20 metres is 8BF, who has worked 1CKP in daylight with only 90 watts input. He is receiving, by the way, on a new kind of 5-valve set, which he calls a "superheterodyne without heterodyne." It appears to work very well.

Although 20-metre work has provided so much of the interest this month, only a few

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stations are at present working on it, and many are still busy on the longer waves.

As was to be expected, the volume of work on 90 metres decreased considerably with the approach of summer, but it is still far from ceasing entirely. 6NF has worked some 20 Americans during the month—a small number compared with those he has worked during previous months. He has also received a number of reports from Australia.

5LF and 2SH have only been on the shorter waves. 6QB has spent the month working stations all over Europe in daylight on less than one watt. He has also worked American 2ZB on 4 watts.

Mr. E. J. Martin, of Cobham, whose work in reception figured in several of these reports last year, is now known as 2BAW. He has heard a considerable number of Americans this month on 20 metres.

6UV worked 26 Americans during March, bringing his total to 52. He is still in regular touch with the States. 2XV of Shelford, Cambs, has worked over 200 miles in daylight, and 300 miles telephony at night, all on 9 watts.

Very low power DX seems to be fashionable around London this month.

5TZ, in the Isle of Wight, whose European work has been well known for a long time, is now in touch with America at last. As is usual in transatlantic work, the "first contact" proves to be the difficult one to achieve, and he now works large numbers of Americans. He and 6NG, of Manchester, are both receiving Americans on 20 metres.

Although a large number of Americans are working on 40 metres, I have very few reports about this wave. Presumably, 90 metres is thought more interesting, on account of the two-way work there; but I have one report from Mr. S. F. Evans, of Northumberland, who has received over 50 Americans on 40 metres in a period of three weeks.

5SI, of Shrewsbury, is, I believe, back in action again now after his illness, and is working all Europe and a few Americans on a very small power.

5UQ recently blew his big valve, and celebrated the occasion by working 13 Americans in one night on a small one. The continued use of the small one would seem to be indicated.

There are at least two active stations, 6TD and 6US, in Wales, although the former is soon moving into England. Both of them have worked every European country and a number of Americans.

I should be glad if those sending me reports next month would remark specially on how they find the relative strengths of 90-metre and 20-metre signals as the season advances. I personally expect 90-metre American signals finally to fade out about the end of May, and 20-metre signals to last through the summer.

I also want reports of any Australian or New Zealand signals heard from now onwards, in order to try to establish the seasonal "cycle" in which they appear.

I rather expect a return of these signals in the early summer, for about a fortnight. They are, of course, very occasionally heard now, but by a "return" I mean a period during which they can be heard almost daily, as when we first worked them.

Reports by May 10th, please.

A NEW DUBILIER CONDENSER. [R381·009

A rather novel condenser, the "Duwatcon," has been received for inspection from The Dubilier Condenser Co., Ltd.

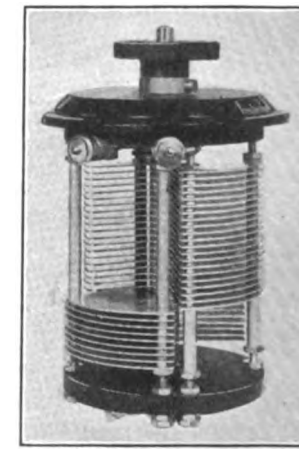
It is specially designed to overcome the usual gap in the wave-length range covered between series and parallel positions of an ordinary aerial condenser.

For this purpose two sets of vanes are provided. The main set extends over 120° of angle, and gives a capacity varying from ·000 028 to ·000 59. Just before this is all in the second small set (which extends over 90° only) begins to enter. This set is always connected across the aerial coil, and when all in amounts to ·000 16.

As a parallel condenser, the range is ·000 028 to ·000 75.

Calculation shows that on any aerial up to ·000 35 capacity there will be an overlap between the maximum wave-length, with this condenser in series and the minimum wave-length with it in parallel.

It is priced at 30s.



The "Duwatcon."

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For the Esperantists.

Extracts from E.W. & W.E., April, 1925.

Resumaro de Artikoloj en E.W. & W.E.

Aprilo, 1925. [R800

HARMONIKOJ. [R146

PROVO korekti unu-du erarojn, kun noto pri uzo de ondmetroj. Ĉu la harmoniko estas beno aŭ malbeno dependas tute de la vidpunkto. Oni povas priskribi harmonikon kiel kurenton aŭ tension de frekvenco, kiu estas ekzakta oblo de iu fundamenta frekvenco.

Unu eraro estas, ke fermita cirkvito, "agordita" al frekvenco de, ekzemple, 1000 kilocikloj (1000 kc = 1000000 cikloj = 300 metroj) estas ankaŭ agordita al la harmonika frekvenco, 2000 kc aŭ 150 metroj. Simpla agordita cirkvito estas bona *filtrilo* por harmonikoj.

La artikolo enhavas kelkajn diagramojn de karakterizaj kurvoj de valvoj. Unu kurvo estas de valvo kun preskaŭ pura sinusa kurvo, kies harmonikoj estas malgrandaj. Estas tamen pli probable, ke la krado havos pligrandan balanciĝon, kiel montrite en alia diagramo, en kiu okazo, la elmeto estas reprezentita de kurvo kun plata supro, enhavanta interalie fortan trian harmonikon. Se la valva kurvo estas simetria ĉirkaŭ la linia mezo de la konstanta krada tensio, devus esti nur neparaj harmonikoj; tio estas, se la fundamento estas de 1 000 kc., la elmeto estos miksaĵo de 1 000, 3 000, 5 000 kc., k.t.p., aŭ 300, 100, 60 metroj, k.t.p. · *ne* la aliaj harmonikoj de 2 000, 4 000 k.c., k.t.p. Sed se la krado ricevus tension aŭ la alta tensio estus ŝanĝita, la pozitiva kaj negativa duonondoj de l'elmeto estus ne-egalaj, kaj la paraj kaj neparaj harmonikoj ambaŭ ĉeestos ĉe la elmeto.

La aŭtoro tiam citas la antenan cirkviton. Oni agordas la antenon al kelkaj frekvencoj samtempe, sed, kun unu aparta escepto, la plialtaj frekvencoj *ne* estas harmonikoj. La naturan harmonikon el la valva sendilo oni aŭdas je ondlongo kiu estas ĝusta suboblo de la fundamenta, ne el la anteno.

Kiam li uzas valvan ondometron la amatoro plej ofte renkontas harmonikojn. La aŭtoro priskribas kio okazas, kiam oni uzas ondometron por kontroli valvsendilon aŭ oscilantan ricevilon. Oni fiksas unu instrumenton kaj varias la kondensatoron de l'alia, kaj oni aŭskultas por pepo audebla kiam ajn la frekvenco de la varianta cirkvito transiras tiun de la fiksita cirkvito; ankaŭ se la varianta cirkvito emisias harmonikojn kaj unu el ili transiras la "fiksitan" frekvencon. Sed krom tio, la fiksita instrumento ankaŭ emisias harmonikojn, kaj tiel oni aŭdas pepon kiam ajn *iu* harmoniko de unu "transiras" *iun* harmonikon de l'alia.

Diagramo ilustras, kio okazas kiam ambaŭ instrumentoj emisias harmonikojn, en la okazo de varianta metro, kiu registras nur ĝis la 20a harmoniko, batanta kontraŭ fiksita oscila ricevilo, kiu emisias nur ĝis la 10a. La diagramo montras nombron da "pintoj" je cititaj frekvencoj, ĉiu el kiuj okazigas pepon. La alteco de la pinto montras la laŭtecon de la peko.

LA PERFEKTA APARATO. [R132

Serio de artikoloj pritraktanta la kvalitojn necesajn en perfekta aparato. La nunmonata parto traktas Altfrekvencan Amplifadon, kaj enhavas detalojn pri la diversaj metodoj de altfrekvencaj kuplecoj.

La tri ĉefaj postuloj por maksimuma efikeco rilate al la valvo estas: 1. Longo de "rekta" karakterizo sufiĉa por ricevi la kradan balanciĝon; 2. Neniom de krada kurento; 3. Funkcio sole ĉe la rekta parto de la kurvo.

La kuplecoj uzataj por altfrekvenca amplifado venas sub du ĉefaj klasoj. La rezistance kuplita amplifikatoro estis multe uzita kiam la amatoroj pli okupis sin pri longonda telegrafado; sed ĉar tiu speco de kupleco ne taŭgas por mallongaj ondlongoj, oni malofte uzas ĝin por altfrekvenca funkciado. La ŝok-amplifikatoro estas ankaŭ

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uzita, sed estas malfacilaĵoj rilate al ĝia desegno por mallongonda funkciado. Oni donas detalojn pri desegno de ŝokamplifikatoro patentita de Miller antaŭnelonge, kiu, li pretendis, estas efektiva por ĉiuj radio-frekvencoj, kvankam ĝi ne bezonas agordon.

Alia speco de kupleco ofte uzata estas la transformatora, kiu, oni ordinare kredas, estas tute malsama je la "agordita anodo," sed ĉar plej multaj transformatoroj uzas rigide kuplitan l-krontraŭ-l proporcion, kun la primario agordita, ĝi estas preskaŭ identa kun la agordita anodo. Tiu ĉi lasta kompreneble havas nur unu volvaĵon, sed bezonas kradrezistancon kaj kondensatoron, dum la transformatoro havas du volvaĵojn kaj ne bezonas rezistancon aŭ kondensatoron, kaj oni povas uzi proporcion malsaman je la l-kontraŭ-l, se oni deziras.

Koncerne la meritojn de la du metodoj, se la dua valvo estas kradkurenta detektoro, la agordita anoda cirkvito estas la pli simpla. Kontraŭe, se la dua valvo ne estas krada detektoro, la transformatoro estas certe preferinda, ĉar oni ne nur povas ŝanĝi la proporcion de la volvaĵoj, sed la kradrezistanco kaj kondensatoro, kiuj neniam povas helpi la amplifadon kaj eĉ ofte malhelpas ĝin, ne estas bezontaj.

Aparte de la speco de transformatoro jam priskribita, oni povas uzi nerigide kuplitan transformatoron. Kvankam ĝi posedas grandan selektivecon, ĝi ne estas vere praktika por ordinara funkciado, ĉar ĝi bezonas tri alĝustigojn : la du kondensatoroj kaj la kuplo de la bobenoj. Oni ankaŭ povas uzi rigide kuplitan neagorditan transformatoron, ku posedas sian propran naturan ondlongon kaj sufiĉe akutan agordon. Tiu speco tamen postulas la posedon de granda aro de interŝanĝeblaj transformatoroj.

Laŭ opinio de l'aŭtoro, la ŝoko Miller estas la plej bona por neagordita aŭ neakute agordita aparato, sed se oni deziras la selektivecon, la rigide kuplita agordita transformatoro estas multe pli bona ol aliaj kuplecoj. Li ankaŭ preferas enŝtopajn transformatorojn ol la speco kun tapaĵoj. Li finas per priskribo pri du specoj de transformatoro, kiuj tute kontentigis lin.

PRI TERMO-KUNIĜOJ.

W. Gordon Edwards. [R251.2

Se oni varmigas aŭ malvarmigas la kontaktpinton de du malsimilaj metaloj, potenciala diferenco okazas, kaj kiam oni fermas la cirkviton, elektra kurento fluas.

Kvankam la rezultanta kurento estas malgranda, ĝi estas grava rilate al la desegno de sentivaj elektraj instrumentoj, kaj estas utiligita komerce, ĉar, kune kun milivoltmetro, oni povas utiligi ĝin kiel tre sentivan miliampermetron. Duddell enkorpigis en unu instrumenton la termo-kuniĝon kaj movadon per sia termo-ampermetro, kie la finoj de la nova bobeno estas solditaj al du pecetoj de speciala alojo, fermitaj per arĝenta plato.

Estas du fenomenoj konsiderendaj, nome, la efektoj Peltier'a kaj Thomson'a, kiuj estas :—

1. La efekto ĉe la termo-kuniĝo estas perfekte inversebla ; se la varmigo de la kuniĝo produktas elektromovan forton, tial elektromova forto produktas varmigon.

2. La kvanto de elektro, kiu pasas trans kuniĝon havas sian propran specifan varmecon.

Diversaj specoj de termo-kuniĝoj kun varmigiloj de nesamaj rezistancoj estas fabrikitaj de bone konataj firmoj, sed la aŭtoro konsilas al la eksperimentisto, ke li fabriku sian propran pro malkareco, sed oni bezonas multan zorgon kaj paciencon.

Estas du metodoj porti varmecon al la kuniĝo :—

1. Terma konduko, t.e. ; efektiva kontakto ; aŭ

2. Radiado kaj konvektado.

La unua havas kelkajn malavantaĝojn, pro la malebleco konstrui la matematikan pinton, kio kreas inversecan eraron kaj alportas kapacitajn ĝenojn. La dua metodo estas preferinda, kvankam ĝi forigas sentivecon, kio ne estas tre grava, escepte se oni entreprenas esploradon au normigadon.

Termo-kuniĝoj estas speciale utilaj por mezuri temperaturojn en neatingeblaj lokoj, kiel ekzemple en transformatoro aŭ je lego de longa distanco. Aŭ la du- aŭ trivoja speco estas uzebla, la konektaĵoj por ambaŭ montrataj sur diagramoj. Tabelo montras la termo-elektromovajn fortojn de diversaj metaloj kontraŭ platinumo je mikrovoltoj.

La aŭtoro donas konsilojn pri la konstruado de instrumento, kiel ankaŭ pri la uzo de la termo-kuniĝo kune kun galvanometro.

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RESISTANCO EN SENFADENAJ CIRKVITOJ.

Lekcio al la Radio-Societo de Granda Britujo de Prof. C. L. Fortescue, je 25a Februaro 1925a.

Tre interesa parolado traktanta la praktikan gravecon de rezistanco. Rilate al valvo, kiu provizas potencon al la cirkvito anstataŭ absorbi ĝin, la rezistanco estas negativa.

Ĉe altfrekvencaj agorditaj cirkvitoj, estas necese malgrandigi la rezistancon, ĉar la selektiveco de riceva cirkvito dependas de la proporcio de la rezistanco al la induktanco, speciale kiam, kiel ofte okazas, signalo interferanta estas multe pli forta ol signalo ricevata; ankaŭ pro tio, ke la efikeco de senda anteno kiel radianto de elektromagnetaj ondoj dependas de la relativaj valoroj de la efektiva rezistanco.

La lektoro tiam klasifikis jene la perdojn de potenco ĉe induktanco: (A) Konduktoraj perdoj, (B) Dielektrikaj perdoj, (C) Perdoj ĉe ĉirkaŭantaj konduktoroj, (D) Perdej ĉe bornoj kaj kontaktaĵoj, (E) Perdoj ĉe fadenfinoj.

Li komparis diversspecajn konduktorojn, inter ili rekta cilindra fadeno, kaj la sama speco volvita; dividita fadeno (kun ĉiu fadeno izolita de la aliaj); maldika strio volvita laŭ plata bobeno. Bobenoj unukaj mult-tavolaj estis komparitaj, sed oni ne povis alveni al definitivaj rezultoj laŭ ĉiuj eblaj cirkonstancoj. Sub la 300-metra ondlongo oni trovis, ke unutavola bobeno estas la plej bona, mult-tavola bobeno estas plitaŭga por la pli altaj ondlongoj.

Rilate al dielektrikaj perdoj, la lektoro akcentis la gravecon de efika izoligo. Li priskribis ekzemplojn de grandaj perdoj trovitaj ĉe certaj bobenoj kaj variometroj kiujn li provis.

Rilate al perdoj ĉe ĉirkaŭantaj konduktoroj, oni pruvis, ke la apudeco de latuno apenaŭ havis efekton je la rezistanco de l'induktanco, sed ke ŝtalo multege pligrandigis la rezistancon. Aliaj flankoj de la temo pritraktitaj estis la altfrekvenca rezistanco de kondensatoroj ĉe kuplitaj cirkvitoj, kaj reakcio.

LONG-DISTANCA INTERKOMUNIKADO.

H. N. Ryan (5BV).

(R545.009.2

Raporto pri dumonta interkomunikado inter britaj kaj aliandaj sendistoj. Jam dum sufiĉe longa tempo kunlaborado kun Usonaj amatoroj estas ĉiutaga afero; lastatempe Britaj amatoroj celas plimalproksimajn kampojn.

Ekzemple, dum la dua duono de Januaro kaj unua duono de Februaro, kelke da Britaj stacioj komencis komunikadon kun diversaj landoj en Sudameriko, precipe kun Brazilio. Dum longa tempo nombro da amatoroj aŭdis la voksignalon WJS, sed povis nek trovi la sendanton nek komuniki kun li. 2NM (tre konata brita amatoro) tamen sukcesis, kaj trovis, ke ĝi estas la voksignalo de la Ekspedicio Hamilton-Rice en la sovaĝejoj de Brazilio. 2MN ankaŭ sukcesis interkomuniki kun la ekspedicio, informante al ili la novaĵojn de la ekstera mondo. Tiu faro estas unu el la plej laŭdindaj en la historio de amatora radio.

Oni ankaŭ povas aŭdi signalojn ĉiunokte el Arĝentino, Ĉilio, kaj Meksikujo, kvankam regula interkomunikado ankoraŭ ne komenciĝis.

Rilate al progreso sur la Kontinento, du Hispanaj stacioj komunikis kun Ameriko, kaj GHH (Brita stacio en Mosul) sukcesis atingi Aŭstralion. Estas interese scii, ke 6TM, brita amatoro, tenas la rekordon pro la nombro de Amerikaj stacioj aŭditaj unu vesperon, 150 dum 5 horoj. 2IL de Southampton estas aŭdita telefone en Finnlando. 5QV faris interesan provon kun la ĉeĥoslovaka OKI.

Je la fino de lasta jaro, kiel oni nun tre bone scias, Britaj amatoroj sukcesis establi du-vojan interkomunikadon per Morso kun Nov-Zelando, tiutempe la plej mirinda faro atingita. Granda nombro da amatoroj interkomunikis kun Nova Zelando dum kelkaj semajnoj, sed poste la signaloj forvelkis pro sezonaj kaŭzoj. Oni tamen atendis aŭdi signalojn denove en Februaro, kaj tiu kredo efektiviĝis, kvankam la signaloj ne daŭris longe, nek ili estis tiel fidindaj. Tamen estas notinde, ke 2OD efektivigis *telefonan* interkomunikadon kun Nova Zelando kaj Aŭstralio, plua rekordo.

En Londono, 6NF kunlaboris kun 160 Amerikaj stacioj kaj aŭdiĝis en Cachar (Hindujo) kaj sur la Pacifika marbordo de Ameriko. 5DN, bone konata en Sheffield, faris provojn per malgranda potenco kun Usono. Kvankam lia potenco estas malpli ol 20 vatoj, liaj signaloj atingis eĉ Kentucky.

Entute la Britaj amatoroj jam faris laboron, pri kio ili povas senti fieraj!

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Letters of interest to experimenters are always welcome. In publishing such communications the Editors do not necessarily endorse any technical or general statements which they may contain.

Aerial-Earth Potentials due to Thunderstorms.

The Editor, E.W. & W.E.

SIR,—The following is my reply to Mr. Desmond Fitz-Gibbon in response to your letter on his behalf.

J. C. JENSON.

Department of Physics,
Nebraska Wesleyan University,
Nebraska.

February 24, 1925.

DESMOND FITZ-GIBBON, ESQ.

DEAR SIR,—A letter has been received from the Editor of E.W. & W.E., stating that you are interested in the voltage obtained across low resistances placed in series between the antenna and the earth. The galvanometer used has a sensitivity of 13·7 mm. per microvolt. In thunderstorm weather, before the storm reaches the immediate vicinity of the apparatus, it is not at all unusual to have deflections of 20 or 30 cm. on the scale. Such deflections for this galvanometer would make a constant difference in potential between the deck and the earth of about 20 microvolts. The resistance of the galvanometer is 18·2 ohms. The resistance of lead wires and ground connections may be disregarded.

When thunderstorms are directly overhead, potentials reaching a magnitude of 5000 volts or more are induced in the deck, causing rapid throws of the galvanometer. These are built up for a short time before a lightning discharge, and then suddenly reduced to nearly zero values. In other words, the steady potential between the deck and the earth is of the magnitude of a small fraction of a volt, but when a thundercloud is overhead, potentials amounting to thousands of volts are induced in the deck or in the antenna, causing violent electrical surges between the antenna or deck and the ground.

Trusting that this answers your question.

I am,
Yours very truly,
Nebraska. J. C. JENSON.

Call Signs.

The call sign 6DO has been allotted to P. M. Dorté (6CV) at "Lynwood," Oatlands Park, Weybridge, Surrey.

We are asked to state that Mr. W. H. Coombs, who owns stations 6KL (fixed) and 5OS (portable), has not been working since Christmas, but hopes to commence again at the end of this month, on wave-lengths of 150-200, 110-115 and 20-40 metres, and would be glad to receive reports on his transmissions. His address is: 29, Alexandra Road, West Park, Chesterfield.

The Editor, E.W. & W.E.

SIR,—The call sign 2BI has been allotted to me. Any reports on transmissions will be welcomed. Wave-length at present in use is 195 metres.

W. S. PALMER,
Elm Field, Lt.-Col.
Calne, Wilts.

The Editor, E.W. & W.E.

SIR,—I should be glad if you would oblige me, as a new but most certainly permanent reader, by publishing the information that my call sign has been changed from 2AUL to 2XY, and that reports of reception from distances over 30 miles would be very welcome

I should also be glad to get into touch with another one of the "gang" who would be willing to conduct tests with me, while all QSL cards will be gladly answered.

GERALD A. JEAPES
"Chandos," (G2XV).
Great Shelford,
Cambs

The Editor, E.W. & W.E.

SIR,—Please note I have been issued the call 2BAK. 10 watts. C.W. or phone.

C. R. JEFFRIES.

25, King's Avenue,
New Malden, Surrey.

Short-Wave Work.

The Editor, E.W. & W.E.

SIR,—I should be grateful if you could find space in your journal to give notice that the station here, operating under the call sign 2DX, will be

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working on 24 metres wave-length each day at 12.00 G.M.T. (mid-day). Reports of reception will be particularly welcome. I shall be glad if you can publish this notification and wish you every success in your efforts to advance the best interests of Wireless Science.

W. KENNETH ALFORD (2DX).

"Rosedene,"
Camberley, Surrey.

Power Factor Measurements.

The Editor, E.W. & W.E.

SIR,—With reference to the table of power factors of various insulating materials which you quote in your March issue, I note that you deplore the non-existence in England of a body similar to the Institute of Radio Engineers. I would, however, remind you of the existence here of the Electrical Research Association, which has this advantage, that it studies the method of test before turning out results.

Further, I would venture to suggest that the values which you quote are most unreliable and misleading. It has been shown that in testing for power factors or permittivity at high or low frequencies, it is most necessary to use mercury electrodes in order to obtain good contact with the material, otherwise the results may be 100 per cent. or more out in some cases. If you will refer to the article from which you took your table, you will see that plain flat metal (solid) electrodes were used, and the results obtained are, therefore, of little value, except perhaps to American engineers. As a matter of fact, I believe the values of permittivity and power factor for nearly all insulating materials are very little different at high or low frequencies.

In accepting American figures, the following should be noted: "In research, the British spend £50 on apparatus and £1,000 on thinking, and get results; the Americans spend £1,000 on apparatus and £50 on thinking, and get lost."

D. V. ONSLOW, A.M.I.E.E.

11, St. Cuthbert's Road,
Cricklewood, N.W.2.

[While we agree with our correspondent that the precise conditions of test have a great influence on the figures obtained for the power factor of insulators, we feel obliged to comment on that part of his letter in which he compares the Institute of Radio Engineers of America and the Electrical Research Association in England, and makes some very disparaging remarks about American research. His remarks may or may not be true, but American research departments at any rate appear to have one useful characteristic, which is that *their results are available*. On writing a letter to our correspondent to this effect, he replied that the results of experiments done at the instance of the Electrical Research Association were published to the members of that Association, and also as papers in the Proceedings of certain learned Societies. We repeat that it is our opinion that to distribute results to the members of the Association is not publication, and that for our purposes all the work done by the Electrical Research Association is actually useless, because it is not available to the public.—E.W. & W.E.]

A Wireless Museum.

The Editor, E.W. & W.E.

SIR,—The Milwaukee Radio Amateurs' Club has started a collection of modern, obsolete and unique radio parts and equipment which is being assembled at the Milwaukee Public Museum where it will be permanently exhibited. This idea has met with the hearty co-operation of everybody and with the help of the "gang" we hope to have an exhibit which will really be an asset to the radio game.

We are asking you for any material whatsoever which would be of interest or value in such a collection. We all have old time "doohickies" and "whatnots" that the club would most certainly appreciate having. Due credit is given to contributors by placing a card on each of the exhibits.

Send along whatever you have and it will be greatly appreciated. Address all packages to Sam Snead, 805, 63rd Avenue, West Allis, Wis.

SAM SNEAD.

The Milwaukee Radio Amateurs' Club, Inc.,
601, Enterprise Building,
Milwaukee, Wis.

A South African Amateur.

The Editor, E.W. & W.E.

SIR,—It may interest some of your readers to listen for my transmissions, which will take place as follows:—

April.	Every evening 17.15 to 17.45—95 metres. Every Saturday at 20.05 to 21.00—95 metres.
May and June.	Every Saturday 20.05 to 21.00. Every Thursday and Sunday morning 00.15 to 00.30. (Thursday and Sunday transmission calling Argentine CB8.)

All times are G.M.T.

The May and June transmissions will be on 95 metres up to and including Wednesday, May 13th, when, if two-way working has not been established with Argentine CB8 my wave-length will be reduced to 70 metres for all transmissions.

The transmitter is a four-coil Meissner using a Phillip's type ZY valve. Input 1 500 volts, 70 milliamps. Aerial current is 1 ampere on 95 metres. Aerial is a single wire "L" (8 gauge wire), 50 ft. high, top portion 38 ft. long. Fan counterpoise of six wires each 55 ft. long is used, no earth being employed. The wave is pure C.W., filament current being supplied from a battery and high tension from a motor generator.

My telegraphic address is "Streeter, care Sidleth, Cape Town." Call letters A4Z.

J. S. STREETER.

Myrtle Grove,
Irwell Street, Observatory,
Cape Town.

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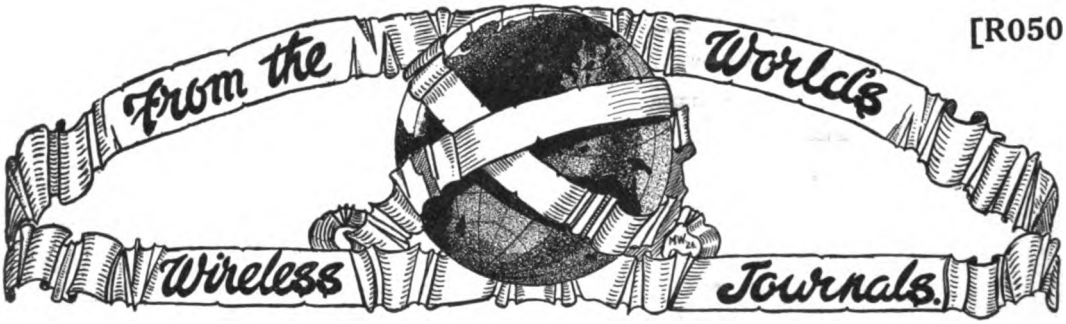

[R050

R000—WIRELESS IN GENERAL.

R000—A PROPOS DE LA PROPAGATION DES ONDES TRÈS COURTES DANS LES TISSUES VIVANTS. —A. Chaulard (*Onde Elec.*, Feb., 1925).

The possibilities of the therapeutic use of very short electromagnetic waves for the treatment of malignant growths within the body are discussed. The suggestion is that stationary waves could be set up within the tissue to produce effects localised at points normally inaccessible. It is pointed out that the velocity of electric waves in living tissue is much less than in air owing to the semi-conducting nature of the tissue, hence the wave-length of the stationary waves produced would be less than the corresponding nominal wave-length in air. Experiments carried out by M. Lakhowsky are cited in which a certain plant affected by a cancerous growth was treated in the manner indicated. The tumour disappeared and the healthy tissue was left unaffected.

R1000.—GENERAL PRINCIPLES AND THEORY.

R113.7—DIE AUSBREITUNG DER ELEKTRISCHEN WELLEN ÜBER DIE ERDE.—A. Meissner (*Jahrb. d. drahtl, Tel. Vol.* 24, *No.* 4).

An article dealing with the problem of the propagation of radio waves over the earth's surface. The author does not hold with the overworked Heaviside layer theory and discredits the attempts of radio engineers, especially the British ones, to explain everything by the assumption of a condition of the upper atmosphere which may not exist at all. It is pointed out that two kinds of radiation can take place from an aerial. There is "surface radiation" due to half-waves just above the surface of the ground which are completed by mirror images below the surface; these waves are always earth-bound. There is also "space radiation," such as is produced by a Hertzian double completely isolated from the ground; this radiation is free to go off on its own in space. The longest wave stations (10 km.) send out only surface radiation while the shortest waves (2 or 3 ms.) are sent out almost entirely as space radiation. The reason for the latter fact is that on short wave-lengths it is usual to operate the aerial on harmonics of its fundamental wave-length, there being a series of nodes and anti-nodes of potential. The aerial wire between two consecutive anti-nodes acts as an isolated Hertzian double. On intermediate wave-lengths (50-2 000 ms.) aerials radiate both surface radiation and space radiation. It is the interference between these two types of radiation which gives rise to night effects and fading. The shorter the wave-length the more rapidly is the surface radiation attenuated by absorption, so that long distance communication on short wave-lengths (below 100 ms.) may be attributed to space radiation alone. No definite explanation of the bending of waves round the curvature of the earth is offered but it is pointed out that light is refracted by the atmosphere when the sun is at low altitudes. It is also suggested that the different gases composing the atmosphere have different specific inductive capacities and that the S.I.C. of a gas is modified by ionisation. In homogeneity of the atmosphere in these respects might account partly for the bending of the path of electromagnetic waves.

R114.—ONZE MOIS D'OBSERVATION DES ATMOSPHERIQUES.—R. Bureau (*Onde Elec.*, Feb., 1925).

Concluding portion of account of some extended observations on atmospherics in particular relation to meteorological conditions. A good deal of experimental data is given in this respect. The writer states that his observations lend no support to the idea held by some investigators that atmospherics have a long range of hundreds or even thousands of kilometres. He concludes that the range of an atmospheric is quite small.

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R142.3.—ERZWUNGENE SCHWINGUNGEN IN ZWEI ABGESTIMMTEN SCHWINGUNGKREISEN, DIE DURCH EISENKERNSPULEN GEKOPPELT SIND.—L. Casper, K. Hubmann and J. Zenneck (*Jahrb. d. drahtl. Tel. Vol.* 24, *No.* 4).

An experimental study of the resonance curves of two oscillatory circuits coupled through an iron-cored transformer.

R200.—MEASUREMENTS AND STANDARDS.

R290.—DÉTERMINATION DU RENDEMENT D'UN GÉNÉRATEUR À LAMPES PAR LA MÉTHODE THERMOMÉTRIQUE.—J. Groszkowski (*Onde Elec.*, Feb., 1925).

A thermometric method of determining the efficiency of valve generators is described. If we can measure the energy dissipated per second as heat in the valve as well as the total input power we can arrive by simple subtraction at the high-frequency power output and hence the efficiency of conversion. To measure this dissipation the bulb of a thermometer is placed in a fixed position near the valve under examination. The thermometer will receive heat from the valve and when the steady state has been attained the temperature indicated by the thermometer will be some function of the rate at which heat is produced in the valve. The apparatus is first calibrated with the thermometer in position by applying a known input power (H.T. volts × H.T. current) to the valve when not oscillating; under this condition all the input power goes to heating up the valve and by varying the input power and noting the corresponding thermometer readings a curve may be plotted showing the relation between thermometer readings and the power expended within the valve. This curve may now be employed when the valve is oscillating under normal conditions to deduce from the thermometer readings how much power is being dissipated in the valve. In spite of the extreme simplicity of this method it is stated that the accuracy may be made within 1 to 2 per cent.

R300.—APPARATUS AND EQUIPMENT.

R374.1.—THE RECTIFICATION OF ALTERNATING CURRENTS BY CRYSTALS.—A. C. James (*Phil. Mag.*, April, 1925).

Various theories of the unilateral conductivity of contacts with certain crystals are discussed. A number of determinations of electrical conductivity were made on a galena-steel contact immersed in paraffin at various temperatures. Galena was found to have a transition point at 160°C., there being an increase in conductivity at this temperature. The addition of silver sulphide was found to increase the rise of conductivity at the transition point. It is concluded that the passage of direct current through galena is accompanied by the formation of metallic threads; this effect being increased by the addition of silver sulphide and decreased by the addition of stannous sulphide. An electrolytic explanation of the rectifying action is favoured. The variation of rectifying properties at different points on the crystal surface can be explained by the fact that the metal ions can move without collision in some planes of the crystal but not in others.

R386.—THEORIE DER KURZEN SIEBKETTEN.—H. Backaus (*Jahrb. d. drahtl. Tel. Vol.* 24, *Nos.* 2 *and* 3).

The theory of short filter circuits is dealt with mathematically. Resonance curves are derived for different types of filters and some experimental results are also given.

R400.—SYSTEMS OF WORKING.

R470.—LA TÉLÉGRAPHIE LE LONG DES RÉSEAUX DE DISTRIBUTION DE LA LUMIERE ET DE L'ENERGIE.—S. and A. Hattowski (*Onde Elec.*, Feb., 1925).

From time to time suggestions have been made for utilising electric supply mains for purposes of telegraphic and telephonic communication without interfering with the normal duty of such mains. This article gives some interesting practical methods of accomplishing this. One method depends upon the fact that the nominally earthed side of a D.C. main is only officially earthed at certain definite points, such as the generating station or distribution centres. There is a small but distinct resistance (0.1 to 0.5 ohn) between the earthed main and a true local earth. Hence if an audio-frequency E.M.F. from a small alternator is applied between this main and earth a voltage is established which can affect a receiver at a distant point on the same supply which is also connected between the main and earth. It is necessary to insert large blocking condensers as it is not permissible to earth an "earthed" main at unauthorised places. A number of practical working arrangements are described. It is said that the distance between the stations has practically no effect on the signal strength. Modifications are described whereby A.C. supply circuits may be used for communication. Particular mention is made of the difficulties encountered in the use of three-phase high-tension lines and how these difficulties can be overcome.

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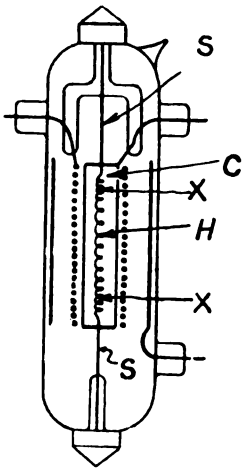
(The following notes are based on information supplied by Mr. Eric Potter, Patent Agent, Lonsdale Chambers, 27, Chancery Lane, W.C.2.) **[R008**

Cathode Construction.

(Application date, March 14th, 1924. No. 225,584.)

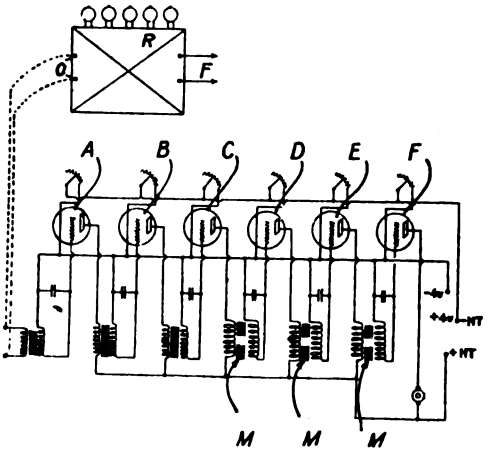
BRITISH Patent No. 225,584 granted to G. C. Beddington, describes a form of equi-potential cathode construction which is illustrated by the accompanying diagram. The object of the invention is to provide a means for heating the cathode equally. It has been found that when an equi-potential cathode takes the form of a cylinder containing a heating element that the cylinder cools rather rapidly towards the ends owing to conduction through the supports. Thus in the accompanying diagram the cathode C is supported at each end at S, and contains a heating coil H. This is of spiral formation, and it will be seen that at V the turns are very much closer together. This results in a greater heating at the ends of the cylinder, and consequently an equal temperature is obtained over the whole surface. It appears, however, from the specification that the heater is simply held in the centre of the cylinder, and the use of a filling of nitrogen between the filament and the inside of the cathode is suggested. We should imagine that some difficulty might arise owing to the diffusion of gas through the heated metal.



Selective Reception.

(Application date, December 4th, 1923. No. 225,704.)

British Patent No. 225,704 has been granted to Y. Marrec for a selective system of reception. Readers will no doubt remember that Marrec demonstrated his system some little while ago. The specification, however, is rather vague and it is really not quite clear exactly how the scheme functions. Referring to the illustration, the signals are received on an open or closed aerial and are applied to the terminals F of the receiver R. This receiver comprises an ordinary radio frequency amplifier, a rectifier and a few stages of audio frequency magnification. The signals



are obtained by beat reception and the output terminals Q deliver an audio frequency signal to the input I of the eliminating device. It is stated that the first three valves, A B and C, act as aperiodic repeaters, and that the amplification obtained therefrom is substantially nil. The last three valves, D E and F, are coupled by iron core transformers having movable cores M. It is stated that the valve D acts as a limiter, the limiting action being controlled by adjusting the filament rheostat. The valve E acts as a selector, and the valve F acts as an autodyne relay. Apparently the last valve generates audio-frequency oscillations, and is controlled by the incoming signals, or in other words, the incoming signals cause continuous oscillations to be produced, which beat with it. It is a pity that the specification is not clearer, as it is almost totally impossible to determine the manner in which each valve is supposed to function.

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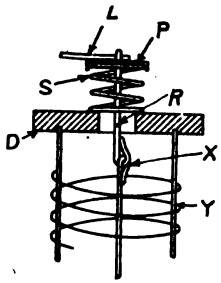
A Filament Support.

(*Application date, August 30th*, 1923. *No.* 225,293).

C. Seymour, D.S.O., and H. G. Hughes describe in British Patent No. 225,293 a form of filament mounting which is illustrated by the accompanying diagram. The invention relates to the familiar filament tension spring. A wire strip or ribbon R is fixed to the end of the filament at X, the other end of the ribbon being attached to a plate P. An insulating disc D is provided with a hole through which the ribbon R can pass, and a spring S is placed between the under side of the plate and the top of the disc D. A filament lead L, of course, is attached to the top of the plate, while the insulating disc D, which may be made of silica or similar material, can be attached to the grid Y.



Maintaining Vacua.

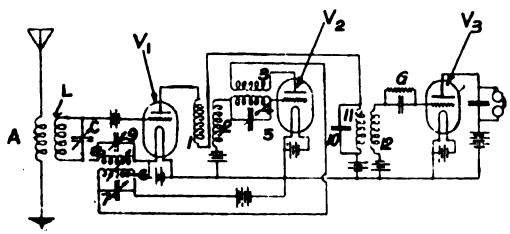
(*Application date, November 12th*, 1923. *No.* 225,694.)

L. A. Levy describes in British Patent No. 225,694 a method of maintaining a vacuum within a hard valve. This consists of placing within the bulb a small quantity of highly absorbent material, such as silica gel or highly activated charcoal. A further feature of the invention is the impregnation of the charcoal with a substance such as magnesium, lithium, or red phosphorus. The valve is roughly pumped in the ordinary way and the use of ordinary getting methods may be employed. It is stated that in practice it is convenient to place the absorbent material in a side tube connected to the side of the bulb. The use of absorbent material of this nature has been known for some considerable time in connection with devices other than hard valves.

The Latest Armstrong Superheterodyne.

(*Application date, May 9th*, 1924. *No.* 215,785.)

The Westinghouse Electric and Manufacturing Company describe in British Patent No. 215,785 a superheterodyne receiving system which is illustrated by the accompanying diagram. It will be seen that the circuit really amounts to an

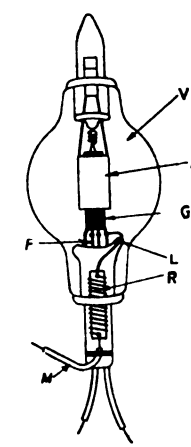


ordinary super-heterodyne system in which the intermediate frequency is reflexed from the first valve. The aerial circuit A is coupled to a circuit L.C, which is tuned to the incoming frequency This secondary circuit is applied to the grid and filament of the valve V1. The anode circuit of the valve V1 contains a radio-frequency transformer 1 2 which also amplifies at the incoming frequency. The secondary of the transformer 1 2 is applied to the grid and filament of the valve V2. The grid circuit of this valve contains a tuned circuit 4 5, and the anode circuit contains the circuit 3. The coil 3 is coupled to the coil 4, causing oscillations to be generated, and the circuit 4 5 is tuned to a frequency equal to half the frequency of the incoming signals plus half the frequency of the desired beat frequency. In this way it will be seen that the first harmonic of the oscillator will differ from the frequency of the incoming signal by the desired intermediate frequency. The anode circuit of V2 also includes the tuned circuit 6 7, which is tuned to the beat frequency, and this is coupled to the circuit 8 9, which is also included in the grid circuit of the valve V1. The grid of the valve V1 therefore has impressed upon it oscillations of beat frequency, and the anode circuit, it will be noticed, also includes a tuned circuit 10 11 tuned to the beat frequency. This is coupled to the coil 12 which is connected across the grid circuit of the valve V3, which includes the grid condenser and leak G and functions as the second rectifier. Considerable details are contained in the specification regarding adjustment and arrangement of the various tuned circuits for the prevention of self-oscillation of the system and other undesirable conditions. The specification also claims the use of a bye-pass filter for this purpose.

Stabilising Valves.

(*Application date, July 12th*, 1923. *No.* 225,899.)

An interesting form of valve construction is described by N. Lea and the Radio Communication Company, Limited, in British Patent No. 225,899. It is well known that when using three-electrode valves there is frequently a considerable tendency for the production of undesirable oscillation, due to the existence of capacity between the electrodes. Various means have been devised for overcoming this difficulty, such as the connection of various external condensers and ohmic resistances. In such cases, however, there is still the possibility of self oscillation occurring, since the external connections of the valve possess inductance which may form oscillatory circuits when combined with the electrode capacities. According to this invention, this difficulty is overcome by the inclusion of an ohmic resistance within the valve itself. Thus, in the accompanying illustration, the valve V contains a normal anode A, grid G and filament F. The lead L from the grid G contains a resistance R, which in this case is housed within a re-entrant tube, the ordinary



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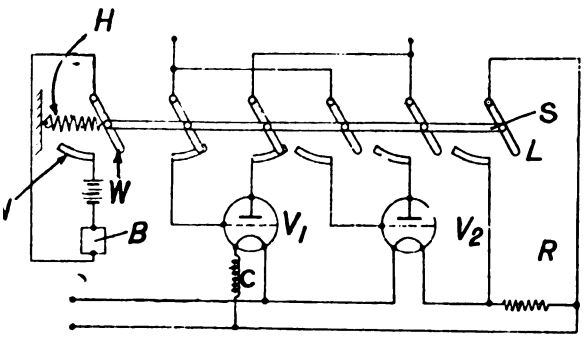
lead M being brought out in the usual manner. Several forms of construction are described in the invention, and consist, for example, in breaking one of the grid supports and including a strip of insulating material, round which the resistance is wound. The specification also claims the use of a number of resistances connected in parallel from several points on the grid. The resistance varies with the type of valve, as well as with external conditions. For example, in a 500-watt valve, the grid leak resistance may be of the order of 100 ohms, while in other cases it may be as low as 10 ohms, or even less.

Maintaining Constant Operation.

(*Application date, October 8th,* 1923. *No.* 226,306.)

E. Y. Robinson, W. J. Brown and Metropolitan-Vickers Electrical Company, Limited, describe in British Patent No. 226,306 a system for maintaining the constant operation of a station which is to be uninfluenced by the sudden burning out of the cathode of one of the valves. The accompanying diagram illustrates the operation of the scheme, which consists essentially in running a main valve on full load, and either running a subsidiary valve with it on a small load, or running a subsidiary valve on no load, and providing a means for instantaneously putting the full load on this valve. Thus in the accompanying illustration valve V1 is connected to its normal radio-frequency circuit by means of a six-pole two-way switch S, which is normally maintained in the position indicated by a spring H. The filament circuit of the valve V1 contains the coil C, which controls the operating mechanism of the switch S.

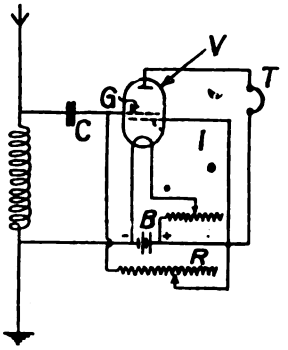


Normally, when the current is passing through the coil C, the switch is in the position shown, but should the filament burn out, the current through the coil C will cease, and cause the switch to move over into the other position. This automatically connects the valve V2 in circuit and the arm L of the switch S short circuits the resistance R, which is in the filament circuit of the valve V2, thereby applying full voltage to the filament. It will be noticed that the switch S is provided with an arm W which makes contact with the segment N and completes a circuit through a warning device B. As soon as the valve V1 fails, it will be seen that the valve V2 is brought into circuit, and this effect is immediately made known by the operation of the warning device.

The "Unidyne" Circuit.

(*Application dates, April 4th,* 1924 *and April 11th,* 1924. *No.* 226,417.)

Readers will no doubt remember that about twelve months ago the popular press boomed the use of a four-electrode valve which operated without the use of a separate anode battery. In particular, readers will no doubt remember the "Unidyne" circuit, which is due to K. D. Rogers and G. V. Dowding, and is described in British Patent No. 226,417. In the accompanying illustration the aerial circuit is simply shown as an inductance L for some reason or other. This is connected through a grid condenser C to the outer grid G of an ordinary four-electrode valve. The grid-leak R is connected, of course, between the grid and the positive side of the filament. The anode potential is obtained from the positive pole of the heating accumulator B, telephones T being included in the anode circuit. The inner grid I is also connected to the positive end of the filament, and the positive potential of the inner grid with respect to the filament tends to neutralise the effect of the space charge. Thus with an anode voltage of the order of 4 to 6 volts the anode current obtained is something of the order of that which is usual with the ordinary three-electrode valve. We are under the impression that the use of a positive potential on the inner grid of a four-electrode valve was known somewhat earlier than April, 1924.



Filament Construction.

(*Application date, November* 12th, 1923. *No.* 226,654.

An interesting form of filament construction is disclosed in British Patent No. 226,654, which is granted to L. A. Levy. The object of the invention is to provide a valve which has a very small current consumption, but at the same time is comparatively robust. Accordingly, instead of making the filament of wire, an infusible core of relatively non-conducting material is employed. This is coated with platinum, or some other metal, upon which is deposited a layer of barium, strontium or thorium compound in any known manner. One method of manufacturing the filament is described, and consists in using a filament core of fused silica which is coated with platinum by treating with a mixture of platinous chloride with oil of rosemary and oil of lavender. Once the first coat has been formed it can be thickened by electrolytic deposition. After this the conducting layer is coated in the normal way.

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EXPERIMENTAL WIRELESS & The WIRELESS ENGINEER

VOL. II. JUNE, 1925. No. 21.

Editorial Views.

Contributions.

IT will be remembered that a short time ago we suggested a series of articles showing how, from a small and reasonably cheap beginning, one could build up by degrees a collection of calibrated apparatus for test work. Our readers will be glad to know that arrangements have now been made for such a series, which will be written in collaboration by two valued contributors who have great experience of such work. Unfortunately, we are not in a position to start the series immediately: it is, of course, being specially written for E.W. & W.E., and, as such material needs especial care in preparation, it will be yet a month or two before it appears.

While we are on the subject of the contents of future issues of E.W. & W.E., we might point out that there are two ways in which readers may help us. First, we are always glad to have suggestions as to subjects which our readers want to see dealt with. Naturally we cannot always follow such suggestions; sometimes the subjects asked for would only interest a very limited circle of readers; sometimes the subject is one of which only a little is known. But, obviously, our one object is, as far as possible, to give what our readers ask for.

One point in particular arises in this connection. Would our readers like to see more of our space devoted to reports of tests on current commercial accessories and components? At present, as will have been noted, we have confined such reports to new apparatus, and have made a very rigid selection; but it would be easy to extend this feature if it would be appreciated.

The second way in which readers can help us is by sending in contributions for consideration. In this regard, we suggest a previous careful perusal of previous issues, as a guide to the type of matter likely to be useful. It is by no means necessary that contributions be highly technical—in fact, at the moment we have almost an excess of this very valuable kind of material.

There are two other kinds of article which we are always prepared to consider favourably. On the one hand, there is the description of new home-made apparatus or experimental work. In connection with apparatus, however, it must be remembered that we do not as a rule give detail descriptions of more or less ordinary receivers. We only do so in cases either where the circuit embodies a really new principle, or where the arrangement has uncommon advantages. "New" experimental work, again, should be something more than a record of long-distance work. Transmission and reception on extra-short waves, records of fading, etc., comparison of various aerials and earthing arrangements, H.T. supply for transmitters, feeding receivers from the mains—these are just a few items that occur to us as we write, all of which offer scope for articles, in addition to the varied opportunities of pure laboratory work.

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Also, there are openings for articles dealing with real working principles, even of comparatively elementary parts of our great subject. But here a word of warning is called for. As we have already stated in our columns, these articles are difficult to write: and the writer must be very, very thoroughly abreast of his subject. We have no use for the sketchy type of elementary article which is, unfortunately, too common, where the writer skates over the surface of his subject and dodges round the thin ice where his knowledge is defective. For E.W. & W.E., elementary articles are welcome, but they must go fairly deep and be very sound.

To those who may fear that their lack of practice in writing may be a handicap, we would say that if the *matter* is there, our own staff will assist in the *manner*, by appropriate editing and revision also; we can always prepare the finished drawings for illustrations—in fact, we prefer pencil sketches, in order that we can finish them in uniform style.

Lastly, a few practical hints. Typewriting is preferred, but not absolutely necessary: but *don't* try and type X's and Y's—hand-write any mathematical matter. Think out the article completely before starting to write it. Follow the universal practice of using one side only of the paper, and space the writing well to allow of revision and correction if necessary. Send a stamped envelope for the return of the MS. if it should prove unsuitable; do not be insulted if this should unfortunately occur; and remember that there must, as a rule, be some months between the acceptance of an article and its appearance.

Aerial Tuner Design.

An interesting article which commences in this issue deals with the question of the best proportions of aerial tuning inductance and capacity when making due allowance for the constants of the aerial itself and the load introduced by the detector.

The authors give in their article the full analysis of the problem; but it may be useful to note here a few of their conclusions in simple language. In general, it may be stated that the presence of aerial tuning condensers, either in series or parallel, is a disadvantage, though there may be occasions when the reverse is the case. Where there is a load (such as a detector) on the circuit, there is a clearly-defined best value of the A.T.I., which increases with the resistance of the load. In many cases, especially with crystals, this "best" value of inductance is not enough to tune to the wave-length required with ordinary aerials. In this case the best step is to increase the aerial capacity as far as possible, and if this is not sufficient, to increase the inductance rather than use a parallel condenser. If this is done, it will be an advantage to tap off the crystal across part only of the inductance, as has been already suggested by other writers. Many other interesting points are brought out in the article, which we hope to complete in our next issue.

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Aerial Tuner Design.

Part I. [R141

By W. B. Medlam, B.Sc., A.M.I.E.E., and U. A. Oschwald, B.A.

IN this article the effect on the efficiency of the tuner of the constants of the aerial and those of its associated tuning circuits is discussed. It is shown that for most efficient reception on a given wavelength there is an optimum value of A.T.I. which depends on the nature of the receiving circuits. The circuits are analysed theoretically and confirmatory experimental results are given.

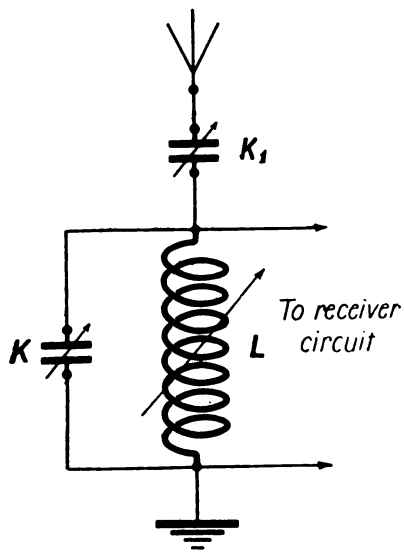

Fig. 1.

The Single Circuit Tuner.

A single circuit tuner may be brought into resonance by varying the A.T.I., or by varying a capacity connected either in series or in parallel with the A.T.I. The general form of the circuit, incorporating all these tuning arrangements, is shown in Fig. 1. This circuit becomes equivalent to that shown in Fig 2 when the constants of the aerial, the resistance of the A.T.I., and the load due to the receiving circuit are taken into account. In Fig. 2, r represents the high frequency resistance of the A.T.I., K_2 the capacity of the aerial in series with the series tuning capacity K_1, and r_1 represents the aerial resistance. The inductance of the aerial may be allowed for by substracting the inductive reactance from the actual capacity reactance of the aerial, and calling the result the effective capacity reactance. In the following, the aerial capacity is taken to be that capacity which has this effective reactance. The receiving circuit will act as a capacity and resistance load on the A.T.I. The resistance component of the load is represented by a constant resistance R. Actually, the value of R, either in a crystal or valve circuit, varies continuously throughout the current or voltage cycle, but the results are consistent with the assumption of some constant effective value of R. The capacity component of the load, and the self-capacity of the A.T.I., are combined with the tuning capacity K (Fig. 1) with which they are in parallel. The sum of these capacities is represented by K_3 in Fig. 2.

The electromagnetic waves from the transmitter set up alternating charges on the aerial capacity K_2. When the circuit resonates, the amplitude of the alternating

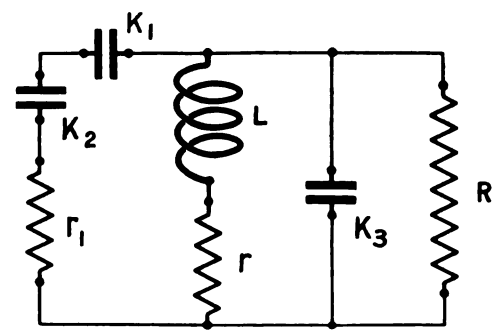

Fig. 2.

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voltage across this capacity will continue to rise until the energy loss per second in the resistances of the circuit just equals the amount of energy per second picked up from the ether. If the latter is constant the alternating voltage across any part of the circuit will then remain at a constant amplitude. We are concerned here only with this final steady state of the circuit. In view of some uncertainty as to whether the aerial E.M.F. remains constant for various loads, we have investigated this point. The results, shown in Appendix A, indicate that it is constant.

Analysis of the circuit shown in Fig. 2 is simplified a little by replacing the series capacities K_1 and K_2 by the equivalent capacity K_4 (Fig. 3), so that

$$\frac{1}{K_4} = \frac{1}{K_1} + \frac{1}{K_2}.$$

Also, it makes no difference to the result if we consider that energy is injected into the

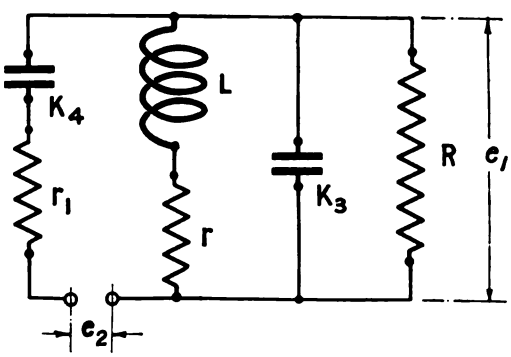

Fig. 3.

circuit by means of a generator e_2 in series with K_4 instead of by the actual means.

Let the voltage across the A.T.I. be represented by

$$e_1 = E_1 \sin \omega t \quad .. \quad .. \quad (1)$$

The total current, i, supplied to the circuit by the generator, is given by the expression

$$i = \frac{E_1 \sin \omega t}{R} + \omega K_3 E_1 \cos \omega t + \frac{E_1}{Z^2}(r \sin \omega t - \omega L \cos \omega t) \quad .. \quad (2)$$

in which $Z = \sqrt{r^2 + \omega^2 L^2}$

The supply voltage,

$$e_2 = E_2 \sin (\omega t + \psi)$$

$$= \left(\frac{r_1}{R} + \frac{rr_1}{Z^2} + \frac{K_3}{K_4} - \frac{L}{K_4 Z^2} + 1\right) E_1 \sin \omega t + \left(-\frac{1}{\omega K_4 R} - \frac{r}{\omega K_4 Z^2} + \omega K_3 r_1 - \frac{\omega L r_1}{Z_2}\right) E_1 \cos \omega t \quad .. \quad (3)$$

or,

$$E_2 \sin (\omega t + \psi) = A E_1 \sin \omega t + B E_1 \cos \omega t \quad (4)$$

where

$$A = \frac{r_1}{R} + \frac{rr_1}{Z_2} + \frac{K_3}{K_4} - \frac{L}{K_4 Z_2} + 1 \quad .. \quad (5)$$

and

$$B = -\frac{1}{\omega K_4 R} - \frac{r}{\omega K_4 Z^2} + \omega K_3 r_1 - \frac{\omega L r_1}{Z^2} \quad (6)$$

We have

$$\psi = \text{arc tan} \frac{B}{A}$$

and

$$\frac{E_2}{E_1} = \sqrt{A^2 + B^2} \quad .. \quad (7)$$

The condition for maximum voltage across the A.T.I. is that E_1 shall be a maximum for a given value of E_2, *i.e.*, $\sqrt{A^2 + B^2}$ shall be a minimum.

When $1/\omega K_4$ has been eliminated by means of the resonance condition $\omega^2 L (K_3 + K_4) = 1$ (1) from Equations (5) and (6) we have

$$A = \frac{r_1}{r} + \frac{r}{Z^2}\left(r_1 + \frac{r}{1 - \omega^2 K_3 L}\right) \quad .. \quad (8)$$

and

$$B = -\frac{\omega L}{R(1 - \omega^2 K_3 L)} - \frac{\omega L}{Z^2}\left(r_1 + \frac{r}{1 - \omega^2 K_3 L}\right) + \omega K_3 r_1 \quad .. \quad (9)$$

Writing p for $r_1 + \frac{r}{1 - \omega^2 K_3 L}$, and q for $1 - \omega^2 K_3 L$ in Equations (8) and (9) gives

$$A = \frac{r_1}{R} + \frac{rp}{Z^2}$$

and

$$B = -\frac{\omega L}{Rq} - \frac{\omega L p}{Z^2} + \omega K_3 r_1$$

From this we can easily show that, writing k^2 for $A^2 + B^2$, and assuming $\frac{\omega L}{Z}$ to be unity,

$$k^2 = \left(\frac{p}{Z} - \omega K_3 r_1 + \frac{\omega L}{Rq}\right)^2 + \frac{r_1^2}{R^2} + \frac{2prr_1}{Z^2 R}$$

(1) More correctly, the resonance condition is $\omega^2 L (K_3 + {}^4K_4) = 1 - \omega^2 K_3 K_4 r r_1$.
The resistance term is negligible with normal values of the quantities involved.

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Substituting the value of p, the last term of the above expression becomes

$$\frac{2rr_1}{Z^2R}\left(r_1+\frac{r}{1-\omega^2K_3L}\right)$$

Now, in general, $1-\omega^2K_3L$ is greater than 0·5, so that the value of the whole expression will never exceed about

$$\frac{2rr_1}{Z^2R}(r_1+2r).$$

As r and r_1 are small compared with Z and R, the expression represents the cube of a small quantity, and may be safely neglected.

Neglecting this term,

$$k^2=\left(\frac{p}{Z}-\omega K_3r_1+\frac{\omega L}{Rq}\right)^2+\frac{r_1^2}{R^2} \qquad (10)$$

or, replacing Z by ωL and neglecting the term $\frac{r_1^2}{R^2}$, we have

$$k=\frac{p}{\omega L}-\omega K_3r_1+\frac{\omega L}{Rq} \qquad .. \quad (11)$$

As $p=r_1+\frac{r}{q}$ the last equation may be written

$$k=\frac{r_1q^2+r+\frac{\omega^2L^2}{R}}{\omega Lq} \qquad .. \quad (12)$$

Since both terms on the right hand side of Equation (10) are positive, the minimum value of k^2 occurs when the first term is a minimum, *i.e.*, the minimum value of

$$\frac{E_2}{E_1}(=k)$$

occurs when

$$\frac{P}{Z}-\omega K_3r_1+\frac{\omega L}{Rq}$$

is a minimum.

Now, we have altogether three variables linked by the resonance condition

$$\omega^2L(K_3+K_4)=1.$$

After using this condition for the elimination of K_4 we are left with the two independent variables L and K_3. We can make the parallel capacity, K_3, the variable and determine the condition under which K_3 shows an optimum value greater than zero, or we can make L the variable.

We will first make K_3 the variable. Differentiating Equation (11) with respect to K_3 and equating to zero for a maximum or minimum gives

$$\frac{dk}{dK_3}=\frac{1}{\omega L}\frac{dp}{dK_3}-\omega r_1-\frac{\omega L}{Rq^2}\frac{dq}{dK_3}=0$$

in which

$$\frac{dq}{dK_3}=-\omega^2L$$

and

$$\frac{dp}{dK_3}=\frac{r\omega^2L}{(1-\omega^2K_3L)^2}=\frac{r\omega^2L}{q^2}$$

Substituting for $\frac{dq}{dK_3}$ and $\frac{dp}{dK_3}$ and multiplying through by $\frac{q^2}{\omega}$ gives the optimum condition

$$r-q^2r_1+\frac{\omega^2L^2}{R}=0$$

Whence

$$q^2=\frac{rR+\omega^2L^2}{Rr_1}$$

and the optimum value of parallel capacity

$$K_3=\frac{1}{\omega^2L}\left(1-\sqrt{\frac{Rr+\omega^2L^2}{Rr_1}}\right) \qquad (13)$$

Thus, in certain circumstances, more fully discussed later, capacity in parallel with the A.T.I. may be beneficial.

Substituting the optimum value of K_3 given by (13) in Equation (11) gives, after simplification,

$$\frac{E_{1(max)}}{E_2}=\frac{1}{k}=\frac{\omega L}{2}\sqrt{\frac{R}{r_1(Rr+\omega^2L^2)}} \qquad (14)$$

We will now make L the variable. Differentiating Equation (11) with respect to L and equating to zero, we have

$$\frac{dk}{dL}=\frac{1}{\omega L}\frac{dp}{dL}-\frac{p}{\omega L^2}+\frac{\omega}{Rq}-\frac{\omega L}{Rq^2}\frac{dq}{dL}=0$$

in which

$$\frac{dq}{dL}=-\omega^2K_3$$

and

$$\frac{dp}{dL}=\frac{r\omega^2K_3}{(1-\omega^2K_3L)^2}=\frac{r\omega^2K_3}{q^2}$$

Substituting these values of $\frac{dq}{dL}$ and $\frac{dp}{dL}$ gives the optimum condition

$$\frac{r\omega K_3}{Lq^2}-\frac{1}{\omega L^2}\left(r_1+\frac{r}{q}\right)+\frac{\omega}{Rq}+\frac{\omega^3LK_3}{Rq^2}=0$$

On substituting the value of q, and rearranging the terms the last equation reduces to

$$\left\{\frac{1-\omega^2K_3^2Rr_1}{R(r+r_1)}\right\}\omega^2L^2+2\omega K_3.\omega L=1 \qquad (15)$$

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The positive root of this quadratic equation gives the value of L which makes the voltage, E_1, across the A.T.I. a maximum. The magnitude of this voltage, or rather the ratio of E_1 to E_2, is obtainable by substituting this optimum value of L in Equation (11). As the final expression so obtained is too complicated to be of much use, the results for three special cases will be considered, and our deductions will be drawn

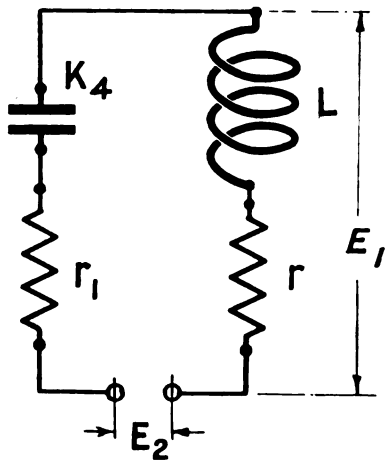

Fig. 4.

from these results. In the first case, of theoretical interest, it is assumed that the receiving circuit produces no loading whatever, and that the A.T.I. has no self-capacity and no parallel condenser. Such conditions are approached in retro-active valve sets. That is, it is assumed that K_3 (Fig. 3) is zero, and that R is infinite. The circuit then reduces to that shown in Fig. 4.

In the second case, particularly applicable to receivers with series tuning only, it is assumed that the loading effect of K_3 is very small in comparison with that of R, and the effect of R is investigated. The circuit for this case is shown in Fig. 5.

In the third case, it is assumed that the load resistance R is great compared with the parallel capacity reactance, and the effect of the latter is investigated. This circuit is shown in Fig. 6.

Case I.—Aerial Circuit Unloaded.

$K_3 = 0$ and $R = \infty$. (Fig. 4).

Although the results for this case may be deduced from equations (7), (8) and (9) they are more easily obtained directly.

Denoting the supply voltage by E_2, and the voltage across the A.T.I. by E_1, we have, when the circuit is resonant:

$$\text{current } (I) = \frac{E_2}{r + r_1}$$

and

$$E_1 = I\sqrt{r^2 + \omega^2 L^2} = \frac{E_2\sqrt{r^2 + \omega^2 L^2}}{r + r_1}$$

So that

$$\frac{E_1}{E_2} = \frac{\sqrt{r^2 + \omega^2 L^2}}{r + r_1}$$

As r is small compared with ωL, we have approximately

$$\frac{E_1}{E_2} = \frac{\omega L}{r + r_1} \quad .. \quad .. (16)$$

As the turns on the A.T.I. are increased, L increases approximately as the square of the turns, while r increases more or less in direct proportion to L if the type of coil is constant; so that for any given value of E_2, the value of E_1 increases to the asymptotic value $\frac{\omega L}{r}$ as the turns on the A.T.I. are increased.

Case II.—Effect of Load Resistance.

$K_3 = 0$. (Fig. 5).

Neglecting terms involving K_3, Equation (15) reduces to

$$\omega^2 L^2 = R(r + r_1) \quad .. \quad .. (17)$$

and Equation (12) becomes

$$k = \frac{r + r_1}{\omega L} + \frac{\omega L}{R} \quad .. \quad .. (18)$$

since, in this case, $q = 1$.

Substituting in (18) the value of L given by (17) we have

$$k = 2\sqrt{\frac{r + r_1}{R}}$$

or

$$\frac{E_{1(max)}}{E_2} = \frac{1}{2}\sqrt{\frac{R}{r + r_1}} \quad .. (19)$$

Case III.—Effect of Parallel Capacity.

R infinite. (Fig. 6).

Neglecting terms involving $1/R$, Equation (14) becomes

$$-\frac{\omega^2 K_3^2 r_1}{r + r_1}.\omega^2 L^2 + 2\omega k_2.\omega L = 1,$$

Whence the optimum value of inductance

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$$L=\frac{1}{\omega^2K_3}\cdot\frac{r+r_1}{r_1}\left(1-\sqrt{\frac{r}{r+r_1}}\right)^3 \quad (20)$$

Similarly, Equation (11) becomes

$$k=\frac{p}{\omega L}-\omega K_3 r_1 \ldots \quad (21)$$

Substituting in (21) the optimum value of L from (20) gives, after simplification,

$$\frac{E_{1(max)}}{E_2}=\frac{1}{k}=\frac{\left(\sqrt{r+r_1}-\sqrt{r}\right)^2}{r_1^2\omega K_3} \quad (22)$$

Also, making $\frac{1}{R}$ equal to zero in Equation (13) gives the optimum value of

$$K_3=\frac{1-\sqrt{r/r_1}}{\omega^2 L} \quad (23)$$

As ω^2K_3L must be positive, r/r_1 must not be greater than unity for this optimum value to be admissible.

Similarly, from Equation (14) we have

$$\frac{E_{1(max)}}{E_2}=\frac{\omega L}{2}\sqrt{\frac{1}{rr_1}} \quad (24)$$

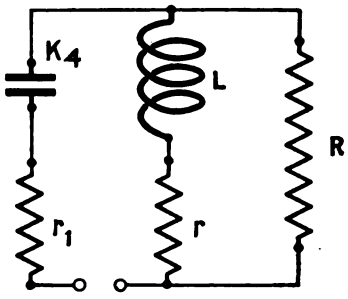

Fig. 5.

The last equation gives the voltage across the A.T.I. using the optimum value of K_3. The fact that this voltage is greater than that obtained when K_3 is zero is easily seen from Equation (21).

Putting $K_3=0$ in this equation gives

$$k=\frac{p}{\omega L}$$

As, in this case, $p=r+r_1$, we have

$$\frac{E_1}{E_2}=\frac{1}{k}=\frac{\omega L}{r+r_1} \quad (25)$$

Since $(\sqrt{r_1}-\sqrt{r})^2$ must be positive, $r_1+r-2\sqrt{rr_1}$ is positive; that is,

$$r+r_1>2\sqrt{rr_1}, \text{ or } \frac{1}{r+r_1}<\frac{1}{2\sqrt{rr_1}}$$

[3] The solution having the positive sign before the square root sign is inadmissible as ω^2K_3L must be less than unity.

Hence, the value of $\frac{E_1}{E_2}$ given by Equation (24) is greater than that given by Equation (25). Thus, when r_1 is greater than r there is a true optimum value of parallel capacity. If r is greater than r_1 the voltage across the A.T.I. increases to the asymptotic value given by Equation (25) when K_3 is indefinitely reduced.

Collecting together the essential formulæ developed above we have the following results :—

Notation.

L =inductance of A.T.I. in henries.
K_3=total capacity in parallel with the A.T.I. (including self-capacity of A.T.I. and capacity of receiving circuit) in farads.
K_4=resultant of aerial and series tuning capacities, in farads.
r =resistance of A.T.I., in ohms.
r_1 =total aerial resistance, in ohms.
R =equivalent resistance of receiving circuit, in ohms.

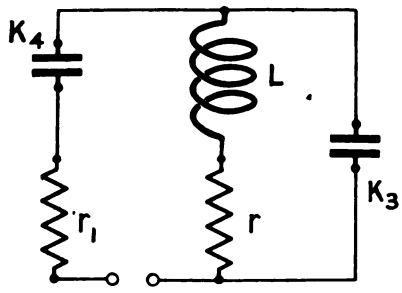

Fig. 6.

E_1=voltage across A.T.I.
E_2=a constant voltage supplied to the circuit.
w $=2\pi\times$frequency.

General Case.

$$\frac{E_1}{E_2}=\frac{\omega Lq}{r_1q^2+r+\frac{\omega^2L^2}{R}} \quad (I.)$$

in which $q=1-\omega^2K_3L$

(*a*) There is an optimum value of parallel capacity

$$K_3=\frac{1}{\omega^2L}\left(1-\sqrt{\frac{Rr+\omega^2L^2}{Rr_1}}\right) \quad (II.)$$

For this value of K_3

$$\frac{E_{1(max)}}{E_2}=\frac{\omega L}{2}\sqrt{\frac{R}{r_1(Rr+\omega^2L^2)}} \quad (III.)$$

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(*b*) There is an optimum value of L, say L_o, given by the positive solution of the quadratic.

$$\left\{\frac{1-\omega^2K_3^2Rr_1}{R(r+r_1)}\right\}\omega^2L^2+2\omega K_3.\omega L-1=0 \qquad \text{(IV.)}$$

With this value of L

$$\frac{E_{1(max)}}{E_2}=\frac{\omega L_0q_0}{r_1q_0^2+r+\frac{\omega^2L_0^2}{R}} \quad .. \quad \text{(V.)}$$

in which $q_0=1-\omega^2K_3L_0$.

Case I.—$K_3=0$, and $R=\infty$. Aerial circuit unloaded.

In this case there is no optimum value of L, and

$$\frac{E_1}{E_2}=\frac{\omega L}{r+r_1} \quad .. \quad .. \quad \text{(VI.)}$$

Here E_1 increases to the asymptotic value $\frac{\omega L}{r}$ as L is increased, if we assume that r is proportional to L at constant frequency.

Case II.—$K_3=O$. Effect of R.

$$\frac{E_1}{E_2}=\frac{\omega LR}{R(r+r_1)+\omega^2L^2} \quad .. \quad \text{(VII.)}$$

In this case there is an optimum value of L given by the equation

$$L=\frac{\sqrt{R(r+r_1)}}{\omega} \quad .. \quad \text{(VIII.)}$$

For this value of L

$$\frac{E_{1(max)}}{E_2}=\frac{1}{2}\sqrt{\frac{R}{r+r_1}} \quad .. \quad \text{(IX.)}$$

Case III.—$R=\infty$. Effect of parallel capacity.

$$\frac{E_1}{E_2}=\frac{\omega L(1-\omega^2K_3L)}{r_1(1-\omega^2K_3L)^2+r} \quad .. \quad \text{(X.)}$$

(*a*) $r>r_1$.

In this case there is no optimum value of K_3, and the value of $\frac{E_1}{E_2}$, given in Equation (X.), increases as K_3 is reduced. When K_3 becomes zero, the right hand side of the equation reduces to that given above in Case I.

(*b*) $r<r_1$.

In this case there is the optimum value of parallel capacity

$$K_3=\frac{1-\sqrt{\frac{r}{r_1}}}{\omega^2L} \quad .. \quad \text{(XI.)}$$

With this value of K_3,

$$\frac{E_{1(max)}}{E_2}=\frac{\omega L}{2\sqrt{rr_1}} \quad .. \quad \text{(XII.)}$$

(*c*) For any values of r and r_1, there is the optimum value of aerial tuning inductance

$$L=\frac{1}{\omega^2K_3}\cdot\frac{r+r_1}{r_1}\left(1-\sqrt{\frac{r}{r+r_1}}\right) \qquad \text{(XIII.)}$$

With this value of L

$$\frac{E_{1(max)}}{E_2}=\frac{(\sqrt{r+r_1}-\sqrt{r})^2}{r_1^2\omega K_3} \quad .. \quad \text{(XIV.)}$$

With regard to Case III. (*b*), Equation (XII.) shows that the voltage across the A.T.I. increases with L. But Equation (XI.) shows that if L is increased the optimum value of K_3 decreases. Thus, the best results are obtainable when K_3 is made as small as possible. We will illustrate this by numerical examples.

Assuming the following numerical values for the constants :—

$\frac{r}{r_1}=\cdot64$, so that $\sqrt{\frac{r}{r_1}}=\cdot8$

$L=100$ microhenries $=10^{-4}$ henries.

$\omega=5\cdot2\times10^6$ (for a wave-length of 360 metres).

From Equation (XI.) the best value of parallel condenser

$$K_3=\frac{(1-\cdot8).10^6}{5\cdot2\times5\cdot2\times10^{12}\times10^{-4}}=.000\,07\mu F$$

and, for this value of K_3, we have from Equation (XII.).

$$\frac{E_{1(max)}}{E_2}=\frac{5\cdot2\times10^6\times10^{-4}}{2\times\cdot8r_1}=\frac{325}{r_1}$$

If we make K_3 zero instead of ·000 07, we have from Equation (VI.)

$$\frac{E_1}{E_2}=\frac{5\cdot2\times10^6\times10^{-4}}{1\cdot64r_1}=\frac{317}{r_1}$$

Thus, in this particular case the parallel condenser of capacity ·000 07μF increases the voltage across the A.T.I. in the ratio $\frac{325}{317}$—an increase of 2½ per cent.

If we increase L to 200 microhenries, retaining the previous values of $\frac{r}{r_1}$ and ω, the optimum value of K_3 is now only ·000 035μF, and with this value of K_3,

$$\frac{E_1}{E_2}=\frac{650}{r_1}$$

If K_3 is zero,

$$\frac{E_1}{E_2}=\frac{634}{r_1},$$

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showing that the parallel condenser again increases the voltage $2\frac{1}{2}$ per cent.; but the voltages in the second case are double what they were before with the smaller value of L.

The above calculation is not quite an accurate comparison of the two cases, for we assumed that when L was doubled, $\frac{r}{r_1}$ remained unchanged. If we assume that the larger coil has the same power-factor as the smaller, the resistance r of the A.T.I. will be approximately twice its original value. Thus $\frac{r}{r_1}$ will be increased to $2 \times \cdot 64 = 1\cdot 28$, and $\sqrt{\frac{r}{r_1}}$ will be $1\cdot 13$.

Using these corrected figures there is no optimum value of K_2, as $\frac{r}{r_1}$ has become greater than unity.

With zero value of K_2,

$$\frac{E_1}{E_2} = \frac{546}{r_1}$$

Here the previous advantage of the parallel condenser disappears as $\frac{r}{r_1}$ exceeds unity. The voltage across the A.T.I. is reduced from $\frac{650}{r_1}$ to $\frac{546}{r_1}$—a reduction of 16 per cent. if r_1 remains unchanged[7]—due to the increase in resistance of the A.T.I.

We have dealt with Case III. (*b*) at some length as this was the only case in which a parallel tuning condenser appeared to justify itself. But we have seen that it is only of use in cases where the inductance of the A.T.I. is too low for efficient working without the condenser. Better results are obtainable by increasing the inductance of the A.T.I. to the optimum as limited by the unavoidable parallel capacity and employing series tuning. The importance of keeping down the self-capacity of the A.T.I. and the capacity of the grid-filament circuit is that by reducing these capacities to a minimum we are able to force up the optimum value of L.

It may be as well, perhaps, to point out that if the value of L is increased beyond the optimum value the voltage across the A.T.I. is reduced. The circuit may be tunable with a series condenser when the inductance is a long way above its optimum value—as is shown by the experimental results given below.

We will now discuss the effect of the resistance loading of the receiving circuit. Reverting to Case II. we see that the voltage across the A.T.I. has its maximum value when the inductance has the particular value defined by Equation (VIII.), and that this voltage is directly proportional to the square root of the load resistance R, and inversely proportional to the square root of the total resistance in the aerial circuit. Thus, if we double the former resistance, or halve the latter, E_1/E_2 will be increased 41 per cent. provided that the value of L is suitably readjusted. If R is doubled then L must be increased 41 per cent. (neglecting any change in r due to alteration of L), but if $r+r_1$ is halved L would have to be *reduced* in the ratio of 1 to $\sqrt{2}$.

In the case of a valve the value of R depends on the grid bias and signal strength, and also on the load in the anode circuit.[8] Its value is often not as high as is sometimes imagined, and a useful increase in voltage may be obtainable by putting negative bias on the grid, and thus increasing R. The effect of grid bias on the input grid-filament voltage in the case of an R-type valve is shown later. (See Figs. 12 and 13.)

High frequency valves are often stabilised by putting positive bias on the grids. Unfortunately, this also reduces the grid-filament voltage. It is much preferable to stabilise by damping the plate circuit, or, better still, by one of the neutrodyne or bridge methods. With the neutrodyne, nearly the maximum grid-filament signal volts and the maximum valve amplification may be maintained. With resistance damping of the tuned plate circuit, the valve amplification may be reduced somewhat, but the grid-filament volts are maintained, whereas with positive bias the valve amplification is maintained but the signal voltage on the grid is reduced. Assuming the loudness of the final results to be equal in the last two cases, the quality of telephony signals given by the former method must surely be the better.

[7] Actually r_1 may not remain constant, as it includes the equivalent series resistance of the series condenser, and this resistance may increase rapidly as the capacity is reduced.

[8] See Appendix B for values of R for valves.

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In the case of crystal circuits, where R has a lower value, the equations in Case II. are applicable, but we have to regard these equations in rather a different way. The criterion of efficiency of a crystal circuit is not to get the greatest voltage across the A.T.I., but to get the greatest rectified current through the crystal, *i.e.*, to get the greatest current through a resistance R equivalent to that of the crystal circuit.[9]

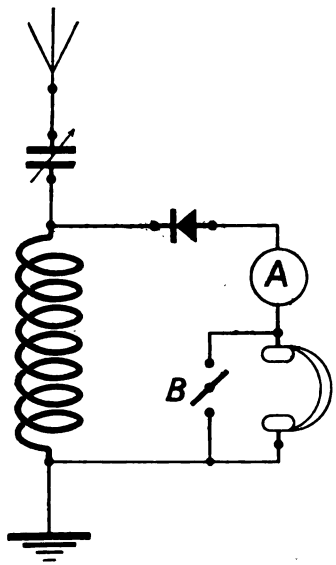

Fig. 7.

Denoting the crystal current obtained with the optimum value of L (as defined in Equation (VIII.) by $I_{(max)}$, we have

$$I_{(max)} = \frac{E_{1(max)}}{R}$$

Substituting for $E_{1(max)}$ from Equation (IX.) gives

$$I_{(max)} \frac{E_2}{2\sqrt{R(r+r_1)}} \quad .. \quad \text{(XV.)}$$

Equation (XV.) shows that the optimum crystal current is inversely proportional to the square root of the equivalent resistance of the crystal circuit. Thus, low resistance crystals, such as the galena type, must give better results than those of high resistance, such as the perikon type, assuming that the crystals have equally good rectifying powers, and that the optimum value of L is used in each case.

Equation (VIII.) shows that the value of L should be lower for the galena crystal than for the perikon. In either case L will be very much lower than is required for a valve circuit.

The best value of L for a crystal circuit is a matter of considerable variation. It depends on the type of crystal and on its adjustment. It also varies with the signal strength, as the crystal resistance varies with the current. Also, the number of pairs of phones in use will affect the result. Quantitative data on these points are given below.

Limitation Set by Aerial Capacity.

We have shown above that capacity across the A.T.I. should be reduced to a minimum, and that the inductance should have a definite value for maximum efficiency on a given wave-length. Thus, in order to tune the circuit, it is necessary to use a series condenser to bring down the resultant aerial capacity to its correct value. This assumes, of course, that the aerial capacity is great enough to enable the series condenser to be used. On present broadcast wave-lengths, *with valve circuits*, indoor and small outdoor aerials may require two or more wires in parallel to bring up their capacity to the requisite value—which is about ·000 2μF. An outside single wire aerial of the full 100 ft. dimensions has sufficient capacity, and there is no advantage to be gained, on the 300 to 500 metre wave-band, by still further increasing the aerial capacity. But if it is desired to obtain the maximum efficiency on longer waves it is necessary to run additional wires in parallel, for the capacity required increases in proportion to the wave-length.

Arrangements may be made to disconnect, and earth, the extra parallel wires when it is required to tune down to short waves.[10]

In the case of crystal circuits the optimum inductance is only about one-third of that required for a valve, and hence an aerial capacity three times greater is required for the crystal. For maximum crystal results on 500 metres, an aerial capacity of about ·002μF is required if the set is tuned with a variometer or tapped coil. With series condenser tuning, the aerial capacity should

[9] See Appendix B for details as to the value of R for crystals.

[10] This arrangement is open to criticism as it would appear that the effective height of the aerial is reduced. However, on our twin aerial we invariably get an increase in signal strength when one-half of the aerial is earthed. This result may be quite exceptional.

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be made two or three times this amount so as to enable the resultant capacity to be brought down to ·002μF.

The average aerial has a capacity certainly not greater than ·000 25μF and the best

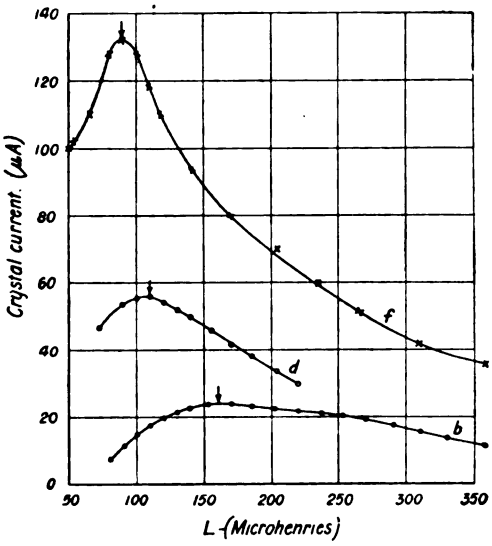

Fig. 8.

possible results with a crystal receiver are not obtainable on such an aerial on wavelengths above about 250 metres.

If, for some reason, it is impossible to increase the aerial capacity to the required value, the next best thing to do is to increase the inductance until it tunes with the full aerial capacity. This method gives greater efficiency than using a smaller inductance value and a parallel condenser. Under these conditions an improvement may be obtainable by tapping the crystal circuit off a portion of the inductance, as advocated by F. M. Colebrook; but while this method secures a better balance between the losses in the various parts of the circuit with a given aerial, in our experience it does not fully compensate for a deficiency of aerial *K*. Using approximately the best aerial *K*, the best crystal tap will be found at, or very near, the extreme end of the coil, giving practically plain coil connections. As the aerial *K* is reduced the A.T.I. must be increased, and the best crystal tap gets further from the end of the coil. At the same time the signal strength gradually decreases at the best crystal tapping.[11]

Experimental Results.[12]

Experimental results confirming the above conclusions will now be given.

Case II.—Effect of load resistance of a crystal.

The connections for the first series of tests on crystal circuits, with series condenser tuning, are shown in Fig. 7. A microammeter *A* was connected in series with the crystal, and a switch *B* was arranged so that the crystal current could be read with the phones (4 000 ohms) short-circuited. Voltages across the A.T.I. were measured on a thermionic voltmeter. Basket coils were used for the A.T.I. These coils were wound initially with a sufficient number of turns to tune with a small value of series capacity. Turns were then removed, step by step, the circuit being kept tuned by means of the series condenser.

The variation of crystal current with the inductance, on 2LO's carrier, is shown by the graphs in Figs. 8 and 9. The curves in Fig. 8 were obtained with the phones short-circuited; those in Fig. 9 with one pair of 4 000 ohms phones in series with the crystal. The curves *a*, *b*, *c* and *d*, refer to high resistance zincite-copper pyrites crystal

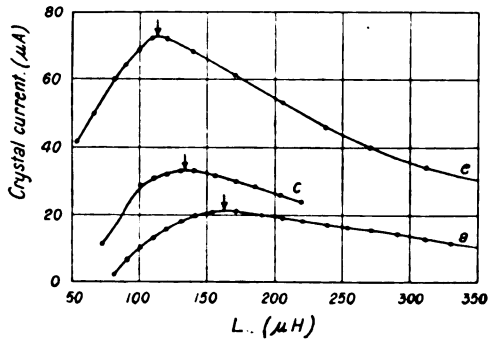

Fig. 9.

combinations. A large number of specimens of these crystals were tried. Curves *c* and *d* refer to the most sensitive, and *a* and *b* to the least sensitive of these specimens. Curves *e* and *f* are representative of the sensitised galena type of crystal with silver catwhisker.

[11] Author's paper on "Best Crystal Circuits," *Wireless World and Radio Review*, August 20 and 27, 1924.

[12] All the experiments described in this article were carried out at the Chelsea Polytechnic.

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The graphs in Fig. 10 show how the voltage across the A.T.I. varies with its inductance with the same crystal loading as for the corresponding graphs (*i.e.*, graphs with the same lettering) in Figs. 8 and 9. The curve *g*, Fig. 10, shows the variation of volts with inductance when the A.T.I. is loaded only with the voltmeter.

Figs. 8 to 10 show very clearly the effect of the resistance of the receiving circuit on the optimum inductance. Taking the extreme cases shown by the curves *f* and *g* we find that with the light loading of the voltmeter the best results are obtained with

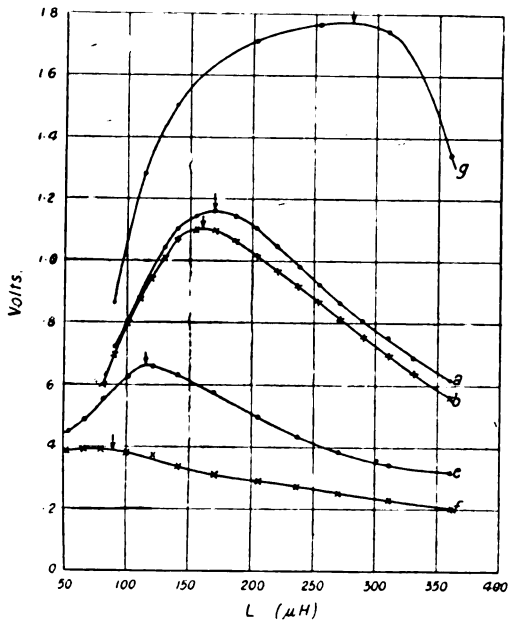

Fig. 10.

an inductance of about 280 microhenries whereas with the heavy loading of a low resistance galena crystal, without phones, the best results are given with an inductance of only 90 microhenries. If the A.T.I. is wound with an inductance of 280 microhenries for the latter circuit the crystal current is only 48 microamps against 132 microamps with 90 microhenries. Conversely, if an inductance of 90 microhenries —the best for the crystal—is used with the valve circuit the grid-filament volts are reduced to 0·86, against 1·77 volts with an inductance of 280 microhenries.

The effect of the number of pairs of phones on the optimum value of *L* is shown in Fig. 11. These curves show the variation of crystal current with inductance for one, two or three pairs of 4 000 ohm phones connected in series with the crystal. The number against each curve indicates the number of pairs of phones to which the curve refers. The curve (*O*) shows the variation of crystal current with *L* with all the phones short-circuited, leaving only the crystal and microammeter across the A.T.I. A "Talite" crystal was used in this case and its adjustment remained unaltered throughout the test.

The chief results are collected in Table I.

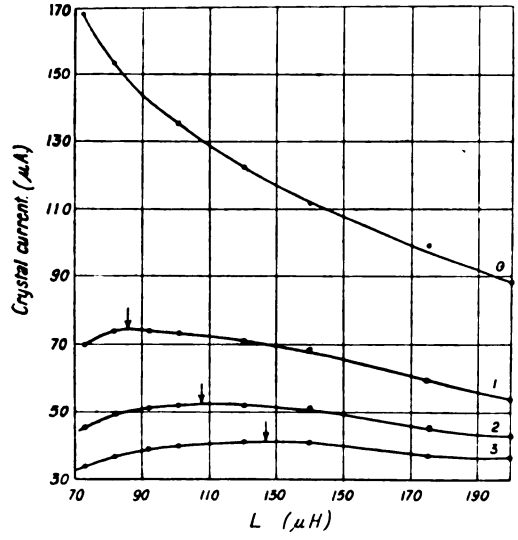

Fig. 11.

TABLE I.

Number of Pairs of Phones in Series.	Maximum Crystal Current.	Optimum Inductance in Microhenries.
0	>168	<73
1	75	86
2	52	108
3	42	127

The curve (o) could not be continued for values of *L* lower than 73 microhenries, as at this point the full aerial capacity—·0004 mF. was in use.

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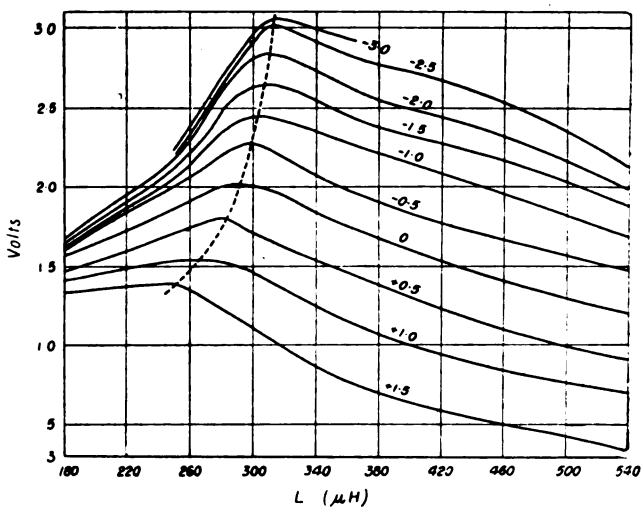

Fig. 12.

Comparing the curve (0), Fig. 11, with (*f*), Fig. 8, and also (1), Fig. 11, with (*e*), Fig. 9, which pairs of curves refer to similar conditions, it will be noted that (0) and (1) which have higher maximum currents also have lower values of optimum inductance respectively than (*f*) and (*e*). This is what would be expected on theoretical grounds, for in the test referred to in Fig. 11 a more efficient aerial was used and the signal strength was greater. As the crystal current was increased its resistance was reduced, and hence the optimum value of L was reduced.

It is surprising that the two sets of curves are in such close agreement, for the readings were taken on different aerials (one having a capacity of ·000 8μF, the other ·000 4μF, and different makes of crystals, phones, and tuning condensers were used. Also, ten months elapsed between the two sets of tests. This is a good testimony to the constancy of 2LO's transmission.

Effect of Valve Detector.

The families of curves in Fig. 12 and 13 show how the voltage across the A.T.I. varies with its inductance for a number of different values of grid bias in the case of an R-type valve. The H.T. was 4 volts only for the curves in Fig. 12 and 70 volts for those in Fig. 13. It was impracticable to obtain a complete range of curves in the latter case as the valve under these conditions became insensitive as a rectifier (no grid-condenser and leak being usable) and accurate calibration of the readings was impossible.

The magnitude of the grid bias, in volts, is indicated by the figures against the curves. The dotted line in Fig. 12 is drawn through the highest points of the curves, and shows that the best value of inductance steadily increases as the grid is made more negative. They also prove that the voltage across the A.T.I. (*i.e.*, the grid-filament voltage) increases as the *optimum* value of L is increased. For example, from Fig. 12 an inductance of 314 microhenries is the optimum for the particular value of grid-filament resistance R given by a grid bias of -3 volts. The corresponding voltage across the A.T.I. is 3·06 volts. With this same value of L, but with $+1$ volts grid bias, the voltage across the A.T.I. is reduced to 1·40 volts. If the value of L is now reduced to 266 microhenries, which is the optimum value for $+1$ volts grid bias, the voltage across the A.T.I. is increased to 1·55 volts.

The variation of the optimum value of L with grid bias is illustrated in Fig. 14, while Fig. 15 shows how the maximum voltage across the A.T.I., using optimum values of L, varies with the grid bias. It will be seen from Fig. 15 that the greatest possible grid-filament voltage is not attained for all values of H.T. until the negative bias reaches 3 volts. As the R.M.S. value of the signal voltage is 3·06, its peak value will be about 4·3 volts. Thus, with the grid biased to -3 volts, the tops of the signal waves

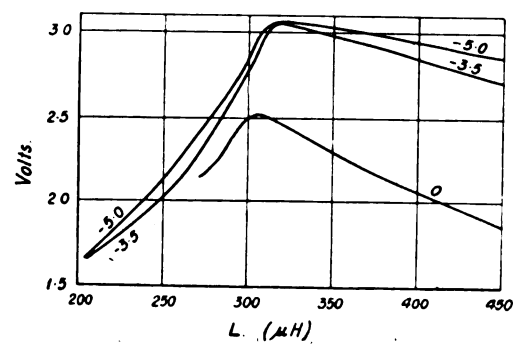

Fig. 13.

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take the grid to a positive potential of 1·3 volts—and some grid current will still flow during parts of the cycle. With 4 volts H.T. the average value of grid current over

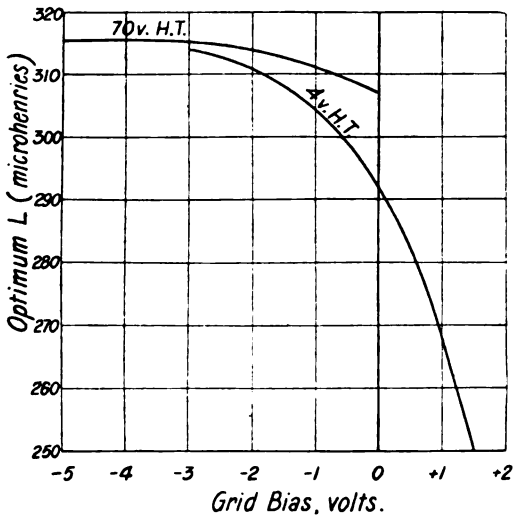


Fig. 14.

the whole cycle was 2 microamperes, and its instantaneous value at the peak of the wave was 20 microamperes. Although there is no appreciable loss of voltage when the grid current is reduced to these limits some distortion of the strong signals will result, as the peaks of the voltage waves will be flattened. To avoid entirely distortion due to

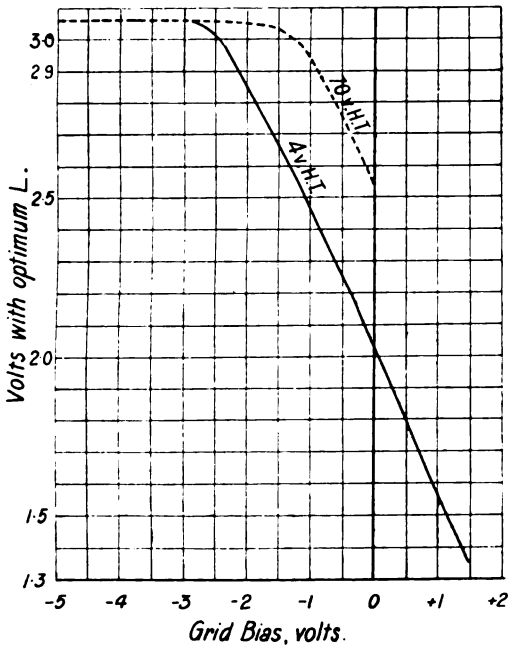
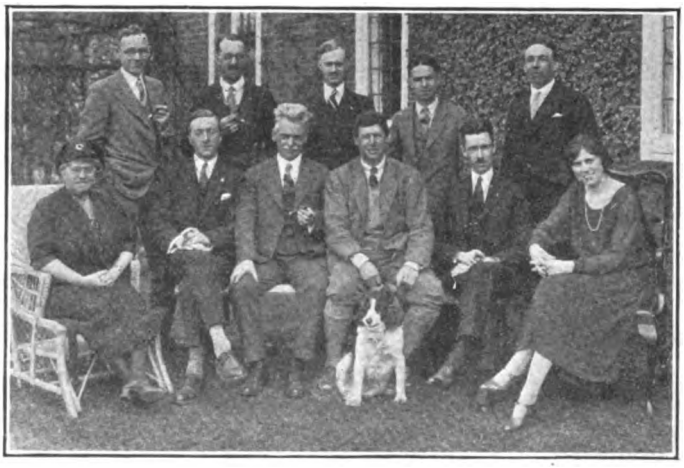


Fig. 15.

this cause it is necessary to bias the grid to —5 volts with signals of 3 volts R.M.S value.

(To be concluded)



A number of the delegates to the recent Conference in Paris at the home of Mr. G. Marcuse (2 NM) just after the Conference closed. Standing (left to right): Mr. Hight (U.S.A.), Major W. C. Borrett (Nova Scotia), Mr. Reid (Newfoundland), Mr. J. Morris (U.S.A.), and Mr. Nicholls (Gt. Britain). Seated (left to right): Mrs. Hiram P. Maxim, M. Mezger (France), Mr. Hiram P. Maxim (Pres. A.R.R.L.), Mr. G. Marcuse, Mr. K. B. Warner (Sec. A.R.R.L.), and Mrs. G. Marcuse.

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A Further Note on Parasitic Losses in Inductance Coils.

By Raymond M. Wilmotte, B.A. **[R382·1**

IN the article which appeared under this heading in last month's E.W. & W.E., through an unfortunate clerical error, the value of the D.C. resistance in the table on page 481 was given as 0.245 ohm instead of 0.405 ohm. I would also like to add a further note on this subject.

It was not my intention to create the belief that the dielectric losses in coils were usually the most important source of their effective resistance—the impression I unwittingly appear to have given a number of people. In fact, the results showing the effect of different materials for the insulation covering of the wires (given in the table on page 481) show that the difference is not very large.

The drastic treatment of plunging the coil into a bucket of water shows a considerable effect with cotton-covered wire, but it is to be supposed that inductance coils are not usually subjected to such treatment. The results were given to show the order of magnitude of the effect which the nature of the dielectric could produce; they also show that the effect is not excessive unless the dielectric is appallingly bad, as wet cotton certainly is.

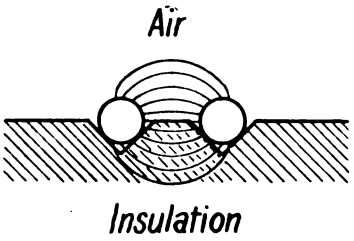

Fig. 1.

A method of estimating very roughly the possible effect of the dielectric in a coil of which the self inductance and self capacity are known was given in the article of last month and resulted in the formula

$$PKL^2C_0\omega^3 \quad .. \quad .. \quad (1)$$

for the added effective resistance due to the dielectric loss, where C_0 is the self capacity with air as the only dielectric, L is the self inductance, and K and P are the "average" dielectric constant and power factor respectively of the insulation. It should be noticed that the products PK and $I/C_0\omega$ have to be large to produce a really large effect for ordinary values of the impedance of the coil. The term may become appreciable, but will rarely be overwhelmingly so.

With further reference to this formula, it was pointed out to me that the meaning of the terms "average" power factor and "average" dielectric constant should be more definitely explained. By these terms I meant the power factor and dielectric constant of an imaginary substance in which the winding of the coil would be completely immersed, and which would produce the same effect as the various insulations which form the dielectric surrounding the coil; that is, it would produce the same self-capacity and the same dielectric loss as in the original coil.

Two cases are of special interest. The first is the case in which part of the electrostatic lines of force can be considered to pass from one turn to another wholly through the air and part wholly through the insulation,

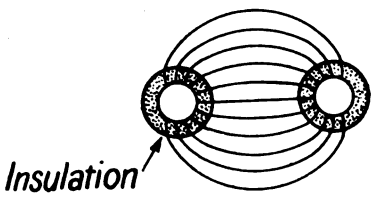

Fig. 2.

as in Fig. 1. This is very often the case for the supporting insulation. In the second case, the lines of electrostatic force pass from one turn to another with part of their path lying in the insulation and the other in the air as in Fig. 2. This is the usual case of the insulation covering the wire.

Let us consider the first case. Fig. 1 can evidently be replaced by two condensers in

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parallel (Fig. 3), one having zero power factor, a dielectric constant equal to unity, and a capacity C_0; the other having a power factor P_1, a dielectric constant K_1 and a capacity K_1C_0'. As a first approximation, we can assume C_0 and C_0' to be independent of K_1—that is of the nature of the dielectric. (This is not strictly true, for a change in the value of the dielectric constant of the insulation will affect the distribution of the electrostatic lines of force.)

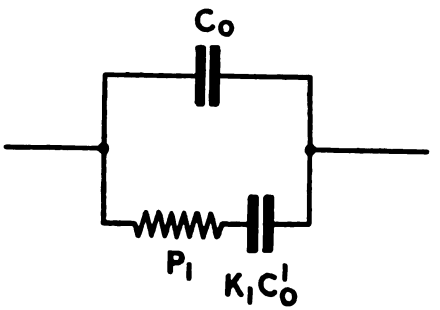

Fig. 3.

With the above assumption, the effective resistance of the combination of the two condensers is

$$\frac{P_1K_1C_0^1}{(C+K_1C_0')^2\omega},$$

and the effective capacity is $(C_0+K_1C_0')$, so long as the power factor P_1 is not excessively large.

Hence the equivalent power factor of the combination is

$$\frac{P_1K_1C_0'}{(C_0+K_1C_0')} \quad .. \quad .. \quad (2)$$

the equivalent dielectric constant is

$$\frac{C_0+K_1C_0'}{C_0+C_0'} \quad .. \quad .. \quad (3)$$

and the product of the dielectric constant and power factor becomes

$$\frac{P_1K_1C_0'}{C_0+C_0'} \quad .. \quad .. \quad (4)$$

If the whole coil could be represented in this way, expressions (2) and (3) would become approximately the "average" power factor and dielectric constant respectively of the insulation of the coil as used in expression (1).

It will be seen that the product of the power factor and dielectric constant is proportional to P_1K_1, which I took as the criterion by which to compare dielectrics. For this case, then, this product still gives the true value by which to compare dielectrics.

Turning now to the second case, it is seen that Fig. 2 can, to a first approximation, be replaced by two condensers in series (Fig. 4), one having zero power factor, a dielectric constant of unity and a capacity C_0, and the other having a power factor P_2, a dielectric constant K_2 and a capacity K_2C_0'', where, as before, it is assumed that C_0 and C_0'' are independent of the value of K_2.

The effective series resistance of this combination is

$$\frac{P_2}{K_2C_0''\omega},$$

and the effective capacity is

$$\frac{K_2C_0''C_0}{K_2C_0''+C_0}.$$

The "average" power factor therefore is

$$\frac{P_2C_0}{K_1C_0''+C_0} \quad .. \quad .. \quad (5)$$

the "average" dielectric constant is

$$\frac{K_2(C_0+C_0'')}{K_2C_0''+C_0} \quad .. \quad .. \quad (6)$$

and the product of the dielectric constant and power factor becomes

$$\frac{P_2K_2C_0(C_0+C_0'')}{C_0+K_2C_0''} \quad .. \quad (7)$$

The whole coil can be represented approximately by a combination of cases similar to the two considered, which are represented by expressions (2) to (4) and (5) to (7). Other cases in which the lines of electrostatic force pass through a series of different dielectrics may occur, and they may be treated in the same way.

It will be noticed, however, that expression (7) is not proportional to P_2K_2, which product has been taken for comparing dielectrics. The dielectric constant K_2 also forms part of it, unless it happens that K_2C_0'' is small compared to C_0, which is only the case when the length of the air path of the lines of force is small compared to the length of their path through the insulation.

In many cases this will admittedly not be so. Since however expression (7) shows that a knowledge of both C_0 and C_0'' is necessary to compare dielectrics, and neither of

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these quantities can at present be evaluated, the product PK can still be considered the best criterion for comparing dielectrics, but it must be remembered that for the second case considered it is at best only an approximate comparison value. Thus from expression (7) we see that for two dielectrics for which the product PK is the same the one having the smaller value of K will be inferior to the other. For the first case, however, we saw that the product PK remains a true comparison factor.

Since the article of last month was published, I have come across a paper which shows that, though my statement—that *I* had not seen the product of the power factor and the dielectric constant mentioned as the true value to compare dielectrics from the point of view of their losses—was at the time correct, that point actually had been emphasised previously.

In this paper, entitled "Power Losses in Insulating Materials," by E. T. Hoch, of the Research Laboratories of the American Telephone and Telegraph and Western Electric Companies, published in *The Bell System Technical Journal* (Vol. I., November, 1922), the product of the dielectric constant and the phase angle is mentioned. The paper says: "Thus it is seen that, while no single factor of the expression can be used to represent the losses, the product of the phase difference and the dielectric constant can be used in this way."

In this paper is given a table of the phase angle, dielectric constant and their product for a number of dielectrics at various radio frequencies and at a number of temperatures.

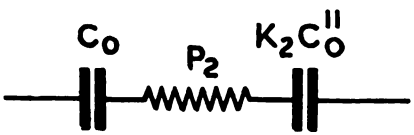

Fig. 4.

The materials are various forms of phenol fibre, oak, maple, birch, ebonite and various glasses (flint, plate, cobalt and pyrex). The frequency range was from about 300 to 1 000 kilocycles and the temperature from about 20°C. to 120°C.

The values for wood are particularly interesting, and I reproduce them in Table I. Unfortunately the effect of temperature on wood is not given .

TABLE I.

Material.	Frequency (kilocycles).	Dielectric Constant K	Phase Difference ψ	$K\psi$
Oak ..	300	3.2	2.1	6.7
,, ..	425	3.3	2.0	6.6
,, ..	635	3.3	2.2	7.3
,, ..	1 060	3.3	2.4	7.9
Maple ..	500	4.4	.9	8.4
Birch ..	500	5.2	3.7	19.2

The effect of temperature on ebonite is also interesting and the values are reproduced in Table II.

TABLE II.

Temperature °C.	Dielectric Constant K	Phase Difference ψ	$K\psi$
21	3.0	0.5	1.5
71	3.1	1.2	3.7
120	3.2	3.7	11.8

This table shows that the quality of ebonite, as far as its dielectric losses are concerned, does not change very much with variations of (ordinary air) temperatures. At higher temperatures, however, it becomes rapidly worse. Fortunately no one is likely to attempt to use ebonite at high temperatures!

I would like to add a remark to the editorial footnote which appeared at the bottom of page 481. The Editor remarked that the self-capacity could be reduced, and more of the dielectric consist of air, if the diameter of the wire were reduced without altering the pitch of the turns. This might in certain cases reduce the dielectric loss, particularly if the turns were wound very close together; but in general I would think that the increase of the potential gradient at the surface of the wire would more than counterbalance this. I wish to point out, however, that any reduction in the resistance of a coil, brought about by a decrease in the diameter of the wire used, would not necessarily be due to the effect explained in the editorial footnote.

From the theoretical formulæ of the copper losses of inductance coils, notably those of

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S. Butterworth (*Phil. Trans.*, Vol. 222, pp. 57-100, 1921, and *Roy. Soc. Proc.*, Vol. 107, 1925), it is seen that the effect of decreasing the diameter of the wire, if the spacing is too close, may actually decrease the effective resistance of the coil, irrespective of any dielectric loss.

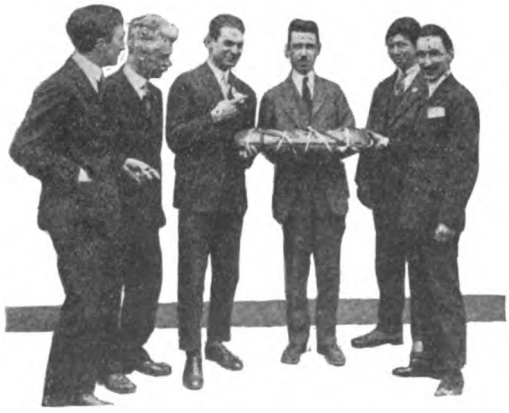
If a big improvement is obtained when the diameter of the wire is reduced, the cause can be put down safely to a reduction in the copper loss and not the dielectric, unless it happens that the dielectric used is ridiculously bad.

It is to be concluded, therefore, that for ordinary commercial coils, the effect of the dielectric loss is not of very great importance, so long as reasonable care is taken in the choice of the materials used ; but this is not always the case.

It is only when very high-class inductance coils are designed that it is worth while paying very particular attention to the use and the choice of the insulating material. Dielectric loss exists, and may sometimes be quite appreciable, but with ordinary care it is generally far from being the most important cause of the effective resistance of inductance coils at ordinary radio frequencies. Unfortunately "ordinary care" does not appear to be taken in the design of many small receiving coils now on the market, and in these cases there is no doubt that considerable improvement could be obtained if dielectrics occupied a greater portion of the designers' thoughts. In transmitting coils the position is quite different. Owing to the large potentials used, the dielectric losses may often be very considerable even in good designs.

The Paris Conference. [R545·06

IT will be remembered that in our last issue we gave a brief *résumé* of the conclusions reached at the International Conference of Amateurs held in Paris just after Easter. This month we are able to publish, almost *in extenso*, a translation of the official report of the discussions and findings of the several sub-committees. The first sub-committee dealt with the constitution of the International Amateur Radio Union. It will be given in full at a later date. In addition, a specially written Esperanto report—not a translation—will be found on page 584.



Following a discussion on the question of forming an international roll of wireless "hams," Mr. Warner, secretary of the A.R.R.L., was presented with the gigantic ham roll shown.

Report of the Second Sub-Committee on Standards and Methods of Working.

The following countries were represented :—

Poland, U.S.A., Italy, Canada, Newfoundland, Great Britain, France, Holland.

The Committee was of the opinion that it is only possible at the present moment to give rather general suggestions on the subject of experiments to be made later on. It suggested that a representative should be nominated for each country whose duty should be to study its problems and to submit its point of view to the Headquarters of the Union.

In the meanwhile, however, the Committee made the following recommendations :—

(1) That standard methods should be adopted for dealing with time, traffic and the transmission of technical details. These points required immediate consideration and it recommended that Greenwich time should be adopted universally, and should be sent in the form of a group of four figures ranging from 0 000 to 2 359. It was suggested that in future the time 24 00 should not be given, as it creates considerable confusion. A system of letters or figures or the combination of the two should be universally adopted to indicate strength of signal and atmospheric conditions in all international tests.

(2) It was requested that there should be appointed for each country a representative of Headquarters to collect all useful details on the subject of tests and pass them to the central office, who will attend to their publication or transmission by broadcasting.

(3) That each country should establish a sufficient number of amateur stations who will undertake to broadcast information from Headquarters.

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(4) In order that tests should be regulated as well as possible to allow the exchange of ideas, there should be established as soon as possible definite international communication at fixed hours between all the countries represented in the Union, which will make it possible to communicate at frequent intervals any messages that may be necessary.

Two photographs taken during the sitting of the International Congress in Paris.

Left: The presiding bench at which can be seen M. Leon Deloy, F8AB, (third from left), Mr. E. Belin, President of the Congress and Inventor of the Telautograph (fourth from left), and Mr. Hiram P. Maxim and Mr. R. B. Warner (seventh and eighth from left; Pres. I.A.R.U. and Sec. A.R.R.L., respectively.

Right: The general assembly, in which a number of prominent people can be recognised.

Sub-Committee for Call Letters.

The following countries were represented :—

France, Great Britain, U.S.A., Holland, Belgium, Italy.

Nationality letters were first discussed, and the following list was approved unanimously :—

A	..	Australia.
B	..	Belgium.
C	..	Canada and Newfoundland.
D	..	—
E	..	Spain.
F	..	France.
G	..	Great Britain.
H	..	Switzerland.
I	..	Italy.
J	..	Japan.
K	..	Germany.
L	..	Luxembourg.
N	..	Holland.
O	..	South Africa.
P	..	Portugal.
Q	..	Cuba.
R	..	Russia.
S	..	Scandinavian Countries.
T	..	Poland, Esthonia and Lithuania.
U	..	U.S.A.
V	..	(Tuning Letter).
W	..	Hungary.
X	..	Portable Stations and Ships.
Y	..	India.
Z	..	New Zealand.
CS	..	Czecho-Slovakia.
é	..	Egypt.
ö	..	Austria.

The representative of Sweden proposed that the letter S for Scandinavian countries should be followed by a different letter or number for each of the following : Sweden, Norway, Denmark, Finland. This proposition was accepted by the other delegates.

The Committee proposed that Central and South American countries, excepting Mexico and Cuba, should use the letter A followed by the first letter of the country, as, for example, AA — Argentine, AB—Brazil, etc., and it was suggested that the letter B should be used in the same way for the Balkan countries, as, for example, BA—Albania, BR—Roumania. For other countries that have at present no transmitting amateurs the Committee suggested that the Union itself should provide call letters.

With the exception of the Colonies of Great Britain, all Colonies should adopt the call letters of the nation to which they belong.

The Committee also discussed the nationality numbers for Europe, and accepted the following numbers, which are already recognised by Governments :—

Italy	1 ;
Great Britain	2, 5 and 6 ;
Denmark	7 ;
France	8 ;
Switzerland	9.

The Committee recommended national associations to propose to their respective Governments the following in addition :—

Finland	3 ;
Germany	4.

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It was suggested that for Belgium and Holland the system actually employed should be continued, in which letters of the alphabet followed by a number are used for Belgium, and the same preceded by the letter P for Holland.

It was recommended that the Association of each country should ask their Government to adopt a single number for the country and to see that it should not be the same as that of neighbouring countries. It was unanimously decided to adopt the American system of calling, in which the call letters of the station wished for are followed by the national letter of the called station, then by the national letter of the calling station and the call sign of the calling station.

Where a CQ call is being sent the dividing letter will be only the national letter of the transmitter.

When it is desired to establish communication at long range, the following call shall be used :

CQ DX x ABC.

in which the small letter x will be replaced by the national letter of the calling station. In order to avoid confusion it is recommended that no national letter shall be used when calling stations which are licensed for receiving only.

An international call book should be published by the Union. The Committee suggested that any national Association of the type of the A.R.R.L. in America, or the A.D.R.S. in Italy, should publish monthly a list of changes of addresses and of new stations licensed ; this should be sent to the general Headquarters of the Union which should undertake to publish supplements whenever there are a certain number of changes.

After a further investigation in full session of the Congress the following propositions were added to those preceding :—

(1) That the approval of the list of national letters was confirmed.

(2) It was confirmed that it is not satisfactory to have the same call-number repeated in neighbouring States.

(3) That the general call-signal CQ should not be repeated more than six times, and the call signals of stations not more than three times.

(4) That as soon as possible the Union should undertake the service of providing call lists kept up to date each month. The service should be offered to those interested, and payment should be made by annual subscription in the same manner as is done for the annual list published at Berne.

Sub-Committee for International Language.

The following countries were represented :—

Germany, England, Argentine, Austria, Canada, Spain, U.S.A., France, Hungary, Italy, Ireland, Japan, Netherlands, Poland, Sweden, Switzerland, Czecho-Slovakia, Newfoundland, Uruguay.

After a long discussion the following resolutions were adopted :—

(*a*) The first International Congress of wireless amateurs, realising the difficulties caused by the diversity of language in International relationships, resolves to recommend the study and employment of Esperanto as an auxiliary language for International communication and radio-telephonic transmissions, as well as in abstracts for translation in the Press and for reports of congresses.

(*b*) The same resolution applies to radio-telegraphic communication when the correspondents cannot understand one another in a National language.

(*c*) According to the above resolutions, the Congress itself adopts Esperanto as its own auxiliary International language in addition to the national languages used.

After these three resolutions had been carried, Mr. Warner of the A.R.R.L. asked that a reservation should be made for any case where Governments should decide later on to adopt another language.

Report of Sub-Committee on Wave-Lengths.

The Wave-length Committee proposed the following bands for use between different countries :—

	metres.
Europe	43 to 47; 70 to 75; 95 to 115.
Canada & Newfoundland ..	41.5 to 43; 115 to 120.
U.S.A.	37.3 to 41.5; 65 to 95
The Rest of the World ..	35 to 37.3; 85 to 95.

This distribution is designed so that on the one hand different tests can be arranged, and on the other hand there would be the minimum of interference between the transmissions of neighbouring countries. With regard to other wave-lengths, the Committee advises that these should be left free to be employed for experimental work generally, while those given above should be kept for International traffic.

The British section of the Congress, among whom will be recognised a number of prominent amateurs.

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More about Errors in Measurement.

By P. K. Turner. [R800:519·8

(CONCLUSION.)

A simplified treatment of the Method of Least Squares, by which experimental results are treated to find the most accurate possible values.

Table I. reads as follows :—

TABLE I.—EXAMPLE I.

Observation.	a'	m'
1	1	7
2	2	8
3	3	10
	3) 6	3) 25
	$a_0 = 2$	$m_0 = 8\frac{1}{3}$

and from it we make out the first part of Table II.

As soon as the first three columns have been filled in, the first check is applied, and we find that $\Sigma a = \Sigma m = 0$; $\Sigma s = n$, as should be the case. The other columns are then filled up, and we find :—

$$A + C = 5 = P\ ;\quad B + C = 7\tfrac{2}{3} = Q,$$

thus fulfilling the second check.

We then have

$$x = \frac{C}{A} = 1\tfrac{1}{2}$$

$$y = m_0 - a_0 x = 8\tfrac{1}{3} - 2 \times 1\tfrac{1}{2} = 5\tfrac{1}{3}.$$

For the probable errors, we have

$$D = B - xC = 4\tfrac{2}{3} - 3 \times 1\tfrac{1}{2} = \tfrac{1}{6}.$$
$$R = Q - xP = 7\tfrac{2}{3} - 5 \times 1\tfrac{1}{2} = \tfrac{1}{6}.$$

The third check being $D = \frac{1}{6} = R$.

From the value of D we have

$$r_x = \sqrt{\frac{\cdot 455 \times \frac{1}{6}}{(3-2) \times 2}} = \sqrt{\cdot 038} = \cdot 195$$

$$r_y = a_0 r_x = 2 \times \cdot 195 = \cdot 38.$$

As a final check, we will fill up Table III.

TABLE III.

Observation.	a'	$a'x$	$a'x+y$	$v = a'x+y-m'$	v^2
1	1	$1\frac{1}{2}$	$6\frac{5}{6}$	$-\frac{1}{6}$	$\frac{1}{36}$
2	2	3	$8\frac{1}{3}$	$+\frac{1}{3}$	$\frac{4}{36}$
3	3	$4\frac{1}{2}$	$9\frac{5}{6}$	$-\frac{1}{6}$	$\frac{1}{36}$
				$-\frac{1}{6}+\frac{1}{3} = 0$	$D = \frac{1}{6} = R$

and we find $\Sigma v = 0$ and $\Sigma v^2 = D = R$, as should be the case. We are therefore justified in saying

$$\left.\begin{aligned} x &= 1\tfrac{1}{2} \pm .2 \\ y &= 5\tfrac{1}{3} \pm .4 \end{aligned}\right\}$$

approximate values being inserted for the probable errors.

TABLE II.—EXAMPLE I.

$a = a' - a_0$				$m = m' - m_0$		$s = a + m + 1$		
Observation.	a	m	s	a^2	m^2	am	as	ms
1	-1	$-1\frac{1}{3}$	$-1\frac{1}{3}$	1	$1\frac{7}{9}$	$1\frac{1}{3}$	$1\frac{1}{3}$	$1\frac{7}{9}$
2	0	$-\frac{1}{3}$	$+\frac{2}{3}$	0	$\frac{1}{9}$	0	0	$-\frac{2}{9}$
3	$+1$	$+1\frac{2}{3}$	$+3\frac{2}{3}$	1	$2\frac{7}{9}$	$1\frac{2}{3}$	$3\frac{2}{3}$	$6\frac{1}{9}$
	0	0	$3 = n$	2	$4\frac{2}{3}$	3	5	$7\frac{2}{3}$
				A	B	C	P	Q

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Unfortunately, practical experimental results do not as a rule fall into convenient whole numbers, so that the work is more laborious. As an example, we will give an actual case of finding inductance and self-capacity, and during the working some special points will be noted. It is perhaps hardly necessary to state that the readings taken were degrees of condenser and wave-meter setting. The corresponding capacities and wave-lengths were worked out from the calibration curves of the instruments, and for each wave-length $\frac{\lambda^2}{3\,550}$ was found, 3 550 being the constant for L in μH and C in mμF. The form of equation shown in (13) was selected, as we had reason to believe that C was probably more accurate than λ^2. Thus

$$C = m'$$
$$C_s = y$$
$$\frac{\lambda^2}{3\,550} = a'$$
$$\frac{1}{L} = x.$$

Five readings were taken.

TABLE I.—EXAMPLE 2.

Observation.	a'	m'
1	10.3	0.000
2	24.9	.091
3	65.1	.312
4	105.8	.543
5	145.5	.769
5)	351.6	1.715
	a_0 = 70.32	m_0 = .343

Next, Table II. was set up. It was worked out on the basis of six-figure accuracy. It will appear later that this was hardly sufficient—seven-figure work would have been better. But it was not realised quite how close the experimental work had been—for it is obvious that the more accurate the test work the more accurate must be the calculation.

On completing the first three columns, we find that the first checks

$$\Sigma a = \Sigma m = 0$$
$$\Sigma s = n$$

TABLE II.—EXAMPLE 2.

	$a = a' - a_0$			$m = m' - m_0$		$s = a + m + 1$		
Observation.	a	m	s	a^2	m^2	am	as	ms
1	— 60.02	— .343	— 59.363	3 602.40	.117 649	20.586 9	3 562.97	20.361 5
2	— 45.42	— .252	— 44.672	2 062.98	.063 504	11.445 8	2 029.00	11.257 3
3	— 5.22	— .031	— 4.251	27.26	.000 961	.161 8	22.19	.131 8
4	+ 35.48	+ .200	+ 36.680	1 258.83	.040 000	7.096 0	1 301.41	7.336 0
5	+ 75.18	+ .426	+ 76.606	5 652.03	.181 476	32.026 7	5 759.24	32.634 2
	—110.66	— .626	—108.286	12 603.50	.403 590	71.317 2	12 674.82	71.720 8
	+110.66	+ .626	+113.286	A	B	C	P	Q
	0	0	5 (=n)					

We can now make out Table I. from the notes of readings taken at the test. These figures are, of course, the basis of all the following work. To save space, the actual derivation of a' and m' $\left(\frac{\lambda^2}{3\,550} \text{ and } C\right)$ from the experimental readings is not shown. The "Least Squares" work begins when it has been done.

are satisfactorily fulfilled. We therefore proceed to the rest of the table. In a future article it is hoped to give some practical hints on doing numerical work of this kind; but for the present we will assume seven-figure logs.

The table being completed, we find

A = 12 603.50 $\quad$ B = .403 6
C = 71.32 $\quad$ C = 71.317 2
Sum = 12 674.82 = P $\quad$ Sum = 71.720 8 = Q

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Our second check is accurate to the last figure, which is unexpected; there is always, of course, the prospect of a discrepancy of one or two in the last figure, but any larger divergence should at once be investigated.

From the results in the table,

$$x=\frac{C}{A}=.005\,658\,53.$$

Now it will be seen by looking onward to equations (IX.), (X.), and (XI.), that we shall use x as a multiplier three times and subtract the results from other numbers. It is good practice to get all three jobs done together, so we set out :—

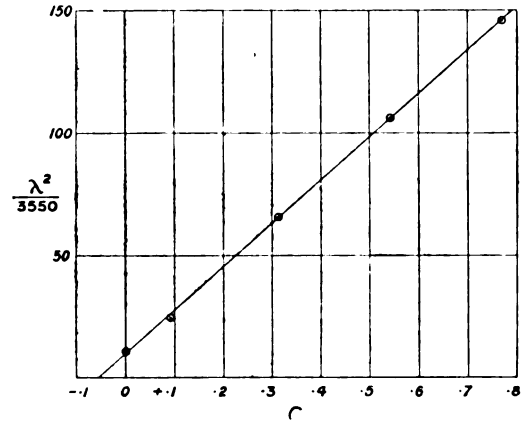
$C=71.317\,2$ $P=12\,674.8$ $a_0=70.32$
x $.005\,658\,53$

$xC=.403\,551.$ $xP=71.720\,7.$ $A_0x=.397\,908.$
$B=.403\,590.$ $Q=71.720\,8.$ $M_0=.343$

$D=.000\,039.$ $R=\ .0001.$ $-y=.054\,908.$

On applying our third check, we find a discrepancy—D does not equal R. But examination shows the reason. Working to six figures, we are likely to find an error of one unit or so in the sixth place. Hence R might very easily have come out anything between 0 and .000 2! As we have already hinted, D and R are very small. The practical work was more accurate than was anticipated, and seven or eight figures should have been used in calculation. This is the point that was raised in discussing equation (XII.) in the body of the article.

Instead of re-calculating Table II. with extended accuracy, we will adopt another device. For, be it noted, we have got x to six figures and y to five—ample accuracy; the inaccuracy in D or R is only going to affect the probable error, not the actual values of x and y. We will work out Table III., which gives



The five readings of Example 2 with the best straight line through them.

us a check figure for D and R with better accuracy than either of equations (X.) and (XI.,) and also gives another check on the general accuracy of the work.

On completing the column for v in Table III., we find that its sum is zero within our limit of accuracy, having an error of two in the last figure. Also, the sum of the last column, Σv^2, is .000 039 57, giving excellent agreement with D. We will, in fact, adopt the value $D=.000\,039\,6$ for our final work, though, as will be seen, we shall not need high accuracy from now onward.

We have for the probable error of x (following equation XIII.) :—

$$r_x=\sqrt{\frac{.455\,D}{(n-2)\,A}}=\sqrt{\frac{.455\times .000\,039\,6}{3\times 12\,603.5}}$$

TABLE III.—EXAMPLE 2.

$x = .00\,5658\,53,\ y = -.054\,908$

Observation.	a'	$a'x$	$a'x+y$	m'	$v=a'x+y-m'$	$(1\,000\,v)^2$
1	10.3	.058 283	.003 375	.0	+.003 375	11.39
2	24.9	.140 897	.085 989	.091	—.005 011	25.11
3	65.1	.368 370	.313 462	.312	+.001 462	2.14
4	105.8	.598 672	.543 764	.543	+.000 764	.58
5	145.5	.823 316	.768 408	.769	—.000 592	.35
			Sums		+.005 601 —.005 603 =—.000 002	39.57

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Since this figure is in any case only an *estimate* of the error; since, in fact, we mean by "probable error" that it is an even bet whether the error in x is greater or less than r_x, it is meaningless to push the calculation for r_x to high accuracy.

We have

$$r_x = .001\sqrt{\frac{.455 \times 39.6}{3 \times 12\,600}}$$

$$= .000\,01\sqrt{\frac{.455 \times 39.6}{3 \times 1.26}}$$

$$= .000\,01\sqrt{4.8} = .000\,022$$

and by equation XIV.

$$r_y = a_0\, r_x = 70 \times .000\,022 = .001\,54$$

We have found $x = .005\,658\,53$,

from which, since

$$L = \frac{1}{x}$$

$$L = 176.725.$$

What, then, is r_L? We can find it thus: The *percentage* error in x is $\frac{100 r_x}{x}$, or approximately .39 per cent. It is obvious, on a little thought, that the *percentage* error in L will be the same as that in x, and we therefore see that r_L must be .39 per cent. of L, or .69μH.

We have now found that the probable error in L is .69—say .7μH, and that in y (— C_s) .001 5mμF. It is therefore quite absurd to give the value of L as 176.725. The final "25" is meaningless, as there may be an error of .7. Similar considerations apply to C_s, so, expressing the latter in $\mu\mu$F, as is more usual for such very small capacities, we have:—

$$L = 176.7 \pm .7\mu\text{H}$$
$$C = 55 \pm 1.5\mu\mu\text{F}$$

the percentage accuracies being 0.4 per cent. for L and about 3 per cent. for C_s.

For ordinary workshop or "drawing-room" conditions, as distinct from those of a first class laboratory, this accuracy is not bad.

But one important point must be noted. The errors above are those incurred *in the test*; they do not provide for errors in the standards by which we are testing. These errors have arisen because, for example, we read our condenser as 140° when it was really 139.9°, and so got, say, .000 8μF instead of .000 799. But there is always the probability that the condenser itself has changed, so that even if we read it correctly at 139.9°, and made no mistake in reading .000 799 from the curve, the capacity might *really* be something different, say .000 805.

In other words, no measurement can be more accurate than the standards it is made by—an obvious point, but one sometimes forgotten.

In this particular case, it is probable that the accuracy of our test is nearly, if not quite, as good as that of our standards. In such a case proper allowance should be made for the errors in the standard.

But two types of error must be distinguished. Suppose that the fixed inductance of our wavemeter had suffered a blow and been changed by 5 per cent. All readings would be affected proportionately, and our results would not show up the error at all. *The Method of Least Squares does not deal with constant or systematic errors.* But if it was the condenser of the wavemeter that had been damaged, so that it was upset irregularly at various points of its scale—now high, now low—this *would* show up as part of our error, and while the "probable error" would show as a larger figure, the values for L and C_s would still be the best obtainable.

As regards irregular errors, the question of errors in the standard condenser leads to a useful rule, so we will consider it. We have already found that our practical work had led to an estimate of 55±1.5$\mu\mu$F for C_s Now suppose that C itself is subject to an uncertainty of 1$\mu\mu$F. Then since C and C_s. enter the original equation as the sum $C + C_s$, this uncertainty must affect the value of C_s found from the equation. One might therefore be tempted to put the uncertainty of C_s at ±2.5 (1+1.5). But this is not so. There is quite a chance that in a series of measurements the error in C might cancel out the other errors.

Here again the mathematicians come to our help with a rule based on theory. We find the error in a sum just as we find the impedance in a circuit, by adding squares and taking the root. This rule leads to a value for r'_c (the error taking account of uncertainty in the standard) of

$$r'_c = \sqrt{(1)^2 + (1.5)^2} = \sqrt{3.25} = \pm 1.8.$$

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Now r_0 and r_L are proportionate, therefore

$$r'_L = r_L \times \frac{r'_C}{r_0} = .7 \times \frac{1.8}{1.5} = \pm .84$$

reducing our accuracy from 0.4 per cent. and 3 per cent. to 0.5 per cent. and 3.5 per cent. approximately.

We might go on to consider errors in the wavemeter, but this is too complicated for accurate calculation, for the percentage error of the wavemeter is a variable quantity, being greatest when the condenser is all in, as far as it is affected by the condenser, but varying with the substitution of coils in so far as it is caused by the coils.

If, however, we care to say that its accuracy is, on the whole, say, 0.5 per cent. at any wave-length, we can say that L will be affected by 1 per cent. (double the error because λ comes in as λ^2). The percentage error of L is then

$$\sqrt{(.4)^2 \times (1)^2} = \sqrt{1.16} = 1.08.$$

Thus the actual error of L, which we will call r''_L, allowing for error in the wavemeter, is

$$r''_L = \frac{176.7 + 1.08}{100} = 1.9\mu\mu\text{H},$$

from which, by the relation between r_L and r_{Cs},

$$r''_{Cs} = \frac{1.9 + 1.5}{7} = 4\mu\mu\text{F}.$$

It is feared that these notes on the effect of errors in standards are rather sketchy, but a serious exposition would be beyond our limits of space. After all, the main object of this article is to give a definite scheme for finding the errors of the observation experiment itself.

The Perfect Set.

Part IX: Reflex Circuits. [R342·4

We now begin a discussion of this exceptionally efficient and useful class of set.

HAVING tried to elucidate some of the main principles of detection and H.F. and L.F. amplification, we propose to talk about Reflex Circuits.

But before getting down to detailed consideration, there are two matters which we desire to clear up. The first is as to the history of the reflex: for perhaps in this design more than any other there is a widespread misconception as to where the real credit should go.

The first official or public mention of a reflex circuit is as far back as 1913, in British Patent No. 8821 of that year. The invention was a German one, by Messrs. Shlömilch and von Bronk, and was afterwards acquired by Marconi's W.T. Co. It gives details of a typical reflex circuit, which has only had quite minor improvements right up to the present day. During and since the war, however, much has been done in detail, the main credit, in the writer's opinion, being due to Voigt in England, Latour in France, and Grimes in the U.S.A. The present writer has consistently used these circuits since 1915, and without claiming to have achieved anything notable, may, he thinks, justly state that he knows them fairly well.

Secondly, one sometimes hears reflex circuits classified among "freaks": "no use for DX," "no use for broadcast," "only fit for experimenters," etc. We should like strongly to emphasise our considered opinion that this is utter nonsense. Subject to certain limitations, which we will deal with in due course, "reflexing" (to coin a word) need have no adverse influence whatever, either on performance, stability or quality.

Let us now set up a typical reflex circuit, before proceeding to discuss it. It may be useful to show first the H.F. part only, to emphasise how small a difference (in some ways) there is. Fig. 1 shows a straight H.F. transformer-coupled amplifier, with a detector of unspecified type. The only point in which it differs from dozens of similar wiring diagrams is that, instead of placing condensers directly across the H.T. battery and grid battery or potentiometer, the condensers go straight from the low-potential side of the H.F. circuit to filament negative. This is good practice, as the H.F. currents are not then compelled to go along the (sometimes rather long) leads to the battery condenser.

In Fig. 2 this set is turned into a reflex in the simplest possible manner: each

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battery lead is opened and has an L.F. component inserted, and the former "output" terminals are led back *via* a transformer to the first grid.

Now what are the changes produced by this (*a*) in the H.F. amplification, as compared with Fig. 1; (*b*) in the L.F. amplification as compared with a straight amplifier? Well (taking the H.F. side first) in Fig. 1 condenser *A* has across it only a 2- or 3-volt battery. It could almost be omitted, and the H.F. voltage between earth and filament is quite low. In Fig. 2, this condenser has a high impedance across it, and there may be an appreciable H.F. voltage: in other words the filament is not earthed. But this is got over by using the earth connection shown dotted in Fig. 2. This in turn throws condenser *A* into the aerial circuit; but the only effect is to alter the tuning. There are other methods of arranging this input circuit, by which the point is avoided. But they have their own disadvantages, so we will defer consideration of them till later.

Next, we must remember that the detector output contains an H.F. component as well as an L.F. one. Although this component will mostly flow through condenser *B*, there will be an H.F. voltage on the primary of the first L.F. transformer; and owing to the capacity between windings, some sort of an H.F. voltage will appear on the secondary and hence be applied to the grid of the first valve. There is, in fact, some reaction due to reflexing, which will be positive or negative according to the connections of the H.F. transformers, but depending also on their exact tuning. This effect can be bothering in a badly-designed multi-stage reflex, but as a rule is quite unimportant, because reaction will probably be used in any case, and the presence of this extra coupling merely alters the best position of the ordinary reaction adjustment. It can be completely got over by the insertion of a filter at *B* instead of a simple condenser, but it is only under exceptional conditions that we have found this necessary. It is useful for long-wave work at (say) 10 000 metres or over, because when we are confronted with the job of completely separating two components, it is naturally more difficult as they approach one another. To separate 1 000 000 from 5 000 cycles is easy; to separate 15 000 or 30 000 from 5 000 not quite so easy.

Lastly, we have the fact that the input to the valve is increased. But this affects both the H.F. and L.F. sides at once, and we will consider it later.

As regards the L.F. side (apart from the matter just raised above) the most important point is that each winding of each L.F. transformer is shunted by a condenser. These condensers must be large enough to offer a low impedance to H.F.; but if they are too large, they will lead to L.F. distortion by by-passing the highest frequencies and giving an unduly low tone. The question is, then: is there enough latitude between the minimum necessary for the H.F. duty and the maximum permissible for L.F. reasons? Luckily there is ample, although at really long wave-lengths (over 10 000 metres) it is a tight fit. For morse, of course, the matter is not important.

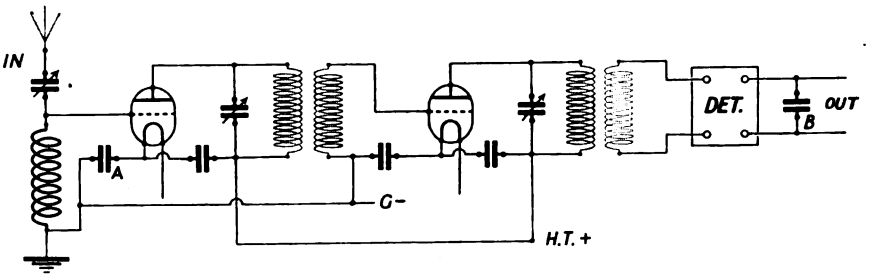

Fig. 1.

There is also the following point. If the aerial is picking up any L.F. disturbances (mains hum, tramline noise, etc.), the L.F. couplings may let it go right through the set. The writer has never, in actual fact, found any trouble from this, but he has heard of it. There are various ways of dealing with it, such as by the "inverse" circuit, to be described later, or by using the first valve as H.F. only.

The last sentence leads us down a side alley. One often sees, in the popular press,

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headlines about a new "three-valve reflex" or "two-valve reflex," and on looking into the circuit finds that it is nothing of the kind. A "three-valve reflex," to our mind, is a set with six stages of amplification, three H.F. and three L.F., all got with three valves (apart from the detector). One particular set we remember described as a "three-valve reflex," consisted of a detector, one H.F. and L.F. dual valve, and one H.F. valve. It was a "one-valve reflex with detector and one H.F." A real "three-valve reflex" is a fairly lively set, but (like any set with three H.F. valves) not too easy to handle.

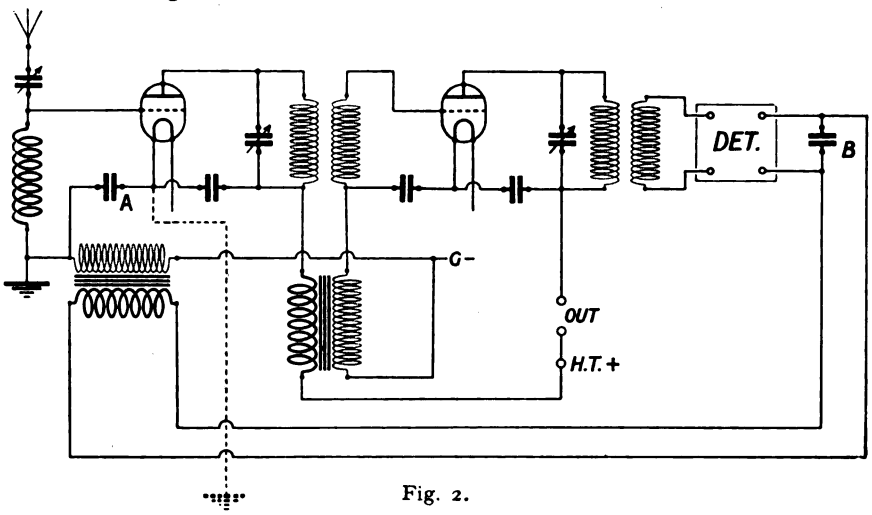

Fig. 2.

Coming back to the high road of our subject, there is yet to be discussed that most important point: the possibility of interaction within the valve between the H.F. and L.F. components. It will, we think, be at once appreciated that by applying both these input voltages to the valve we are increasing the total grid swing, and must use a valve with enough capacity to handle it. But there is rather more in it than this. For instance, examine Fig. 3. Here we are applying an input *HL*, whose two components are *L* and *H*, to a valve. (We assume, of course, that proper bias and H.T. voltages are applied.) The current *H* is meant to be a pure sine-wave, but for simplicity in drawing we are showing it as straight-sided.

The result, as actually got by plotting up and across, as shown at *AAA*, is the current *HLD*, and by subtracting in turn the D.C. component and the L.F. component *L'*, we are left with the H.F. component *H'*. On measuring, we find that *H'* and *L'* are both exact magnified reproductions of the corresponding input. But now look at Fig. 4. Here the valve is overloaded, and on analysing the output (which was obtained as shown by actual plotting across) we find, not only L.F. distortion—a flat-topped curve—but a modulation of the H.F. current. Now remember that the H.F., in our actual reflex, is itself modulated, and that the L.F. component is that same modulation as separated out by the detector, and we see that, according to conditions, we are either going to weaken the incoming modulation or unduly strengthen it. Moreover, it can easily be shown that the distortion thus produced is much more important than that due simply to the flattening of the curve of L.F. output. This means that a slight or moderate

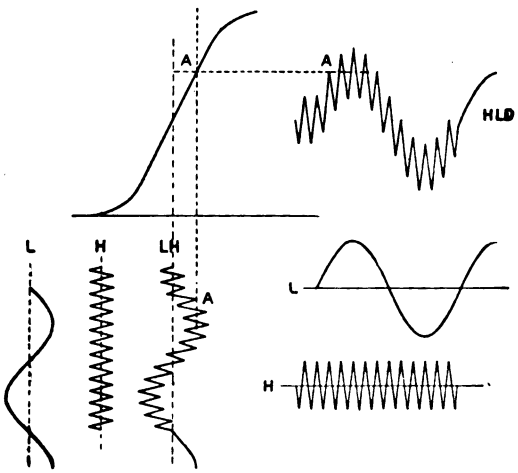

Fig. 3.

curvature of the valve characteristic, not enough to produce noticeable L.F. distortion by its primary effect, may yet upset a reflex due to this modulating action. So that one

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must take care to use good valves, and well within their power. In actual practice we have no difficulty whatever in using ·06 valves, provided we choose a good make with a nice straight characteristic.

The most important limitation of the reflex is due to a phenomenon somewhat akin to the foregoing. It is a limitation, however, which is in some ways a blessing: as a general rule, the reflex is not a suitable circuit for the self-heterodyne reception of C.W. If the reaction is increased to oscillation point the set usually howls aloud. As far as the writer knows, no careful explanation of this has yet been published: but he believes the reason to be the following: Suppose the set to be stable in a non-

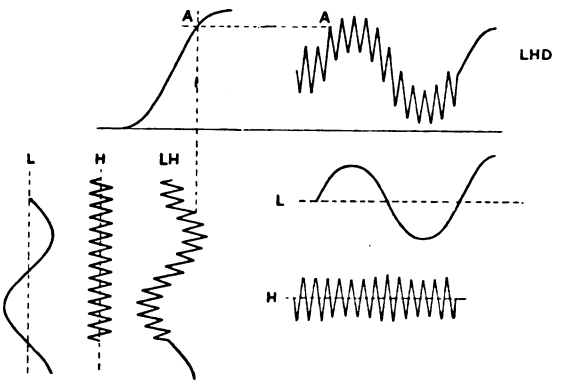

Fig. 4.

oscillating condition, and that the reaction is then increased so that it suddenly bursts into oscillation. There will immediately arise a considerable voltage on the crystal, and hence a large rectified voltage on the primary of the "throw-back" transformer. Owing to the high inductance of the latter, it will take some time—say, 1/1 000 second, for the current through it to reach full value. In fact, if in Fig. 5 curve *a* shows the sudden oscillation, then *b* shows the voltage on the first L.F. transformer primary, and *c* the primary current. The result is a secondary voltage such as *d*. But in actual practice, this secondary voltage is applied to the grid of the oscillator, and immediately causes a decrease in the oscillation strength, causing a new change in *b*. There is thus a periodic change in the oscillation—a modulation in fact—which is duly detected and reproduced as a howl, the frequency depending on the rate of rise of *c*, which in turn depends on the inductance, resistance, and capacity of the transformer.

This limitation is a disadvantage for the DX worker who wants to receive C.W. without the trouble of a separate oscillator. But it is a blessing to the broadcast listener —or, rather, to his neighbours—for it means that he cannot accidentally oscillate without noticing it.

Hitherto we have said nothing as to the detector. It is, in the writer's own opinion, a great virtue of the reflex that it lends itself especially to crystal rectification. The reason is obvious. The reflexed valves are each producing a total amplification of at least 100 times—say 4-5 for H.F. and 20-25 for L.F. The detector, besides rectifying,

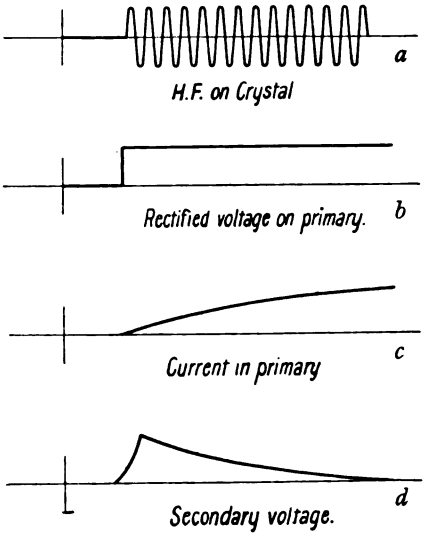

Fig 5.

may produce an effective amplification of 4 or 5. Obviously it is bad economy to use a valve for this purpose. Further, the crystal gives better results on telephony, for which the reflex is most suited, and, again, it has a useful effect in stabilising the H.F. amplifier. Lastly, the crystal in such a set works better than in any other way, for it has a comparatively large input, and is then both efficient and stable. It is quite unnecessary to adjust a galena oftener than once in two or three months, and a zincite pair will go on indefinitely.

In our next part we propose to follow these general notes with a detailed discussion of each part of the "standard" circuit of Fig. 2.

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Insulation Tests.

By C. H. Stephenson. [R280·0122

THE writer was desirous of making rough tests on the insulating properties of various materials used for wireless work, and it occurred to him that some interesting data might be obtained by means of a common gold leaf electroscope. One of these instruments was accordingly made up at a nominal cost, and the results obtained were certainly surprising. The electroscope, in the simple form used in these experiments, is not an accurate instrument, nevertheless it serves its purpose in differentiating between really good and only indifferent insulators.

For the benefit of those readers who are not familiar with the gold leaf electroscope, it may be explained that this simple device consists of two strips of gold leaf (say 1½ in. by ¼ in.) which hang vertically downwards from the end of a well-insulated metal rod. The leaves are surrounded by a case, preferably of metal, so as to shield them from draughts. When the leaves are electrified, for example by touching the rod with a piece of ebonite which has been lightly rubbed on the sleeve, they diverge, forming an inverted V, and remain in this position until the charge leaks away through the insulator and, to a lesser extent, through the air. It will be clear that some indication of the insulating qualities of a material may be obtained if a piece of the substance is held in the fingers and the far end brought into contact with the rod to which the leaves are attached. If the material is a good conductor the leaves will collapse instantly; on the other hand a first-class insulator will produce practically no effect. We may say that the time taken for the leaves to collapse is a rough measure of the insulating qualities of the material under test. This was the scheme adopted in the following experiments, the results of which are distinctly interesting.

Tests.

Ebonite.—Various pieces were selected at random from the scrap box, some with the polish removed, others highly polished. The leaves fell very slowly indeed, taking much more than 30 seconds in all cases. There seemed to be no appreciable difference between the polished and unpolished specimens.

(Time measurements greatly exceeding 30 seconds were not recorded.)

It is interesting to note that these pieces of ebonite were not cleaned or prepared in any way. They were ordinary scrap pieces collected during several years.

Valve-holders.—Three types were tested. The grid leg was held in the fingers and the plate leg brought into contact with the electroscope.

(*a*) Home made, with the usual legs mounted on ebonite. Discharge was very slow indeed.

(*b*) Moulded flange type. Discharge was instantaneous both when cold and after warming.

(*c*) Moulded type without flange, composition different from (*a*). Discharge instantaneous.

Here again the excellence of ebonite shows up, as the home made holder had been in use, exposed to light and dust, for over a year, nor was it cleaned before being tested.

Coil-holder.—This was of the double type, the material being ebonite. Make unknown. The tests were made between the socket and plug of each half. Both parts discharged in 30 seconds.

This was quite a good result considering the dirty condition of the holder.

Condensers.—

(*a*) *Variable.*—Vernier type, with two moving plates and ebonite insulation. The test was made between the fixed and moving plates at minimum capacity. Discharged in 10 seconds.

(*b*) *Fixed.*—Standard pattern of well-known make. Capacity 0.005mF.

The first test was made between the fixing lugs, that is to say, the leakage was through the moulded case.

When cold, discharge occurred in 4 seconds; after warming, this increased to over 30 seconds. The next test was for leakage between the wax filling on the under side and one terminal. Discharge took place in 25 seconds when cold.

The same tests were made in a similar

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pattern of condenser but of a different make. Capacity 0.000 3mF.

Test 1.—Discharged in 6 seconds.

Test 2.—No apparent leakage.

Valves.—Several types were tested, the method being to hold the grid leg in the hand and touch the electroscope with the plate leg.

All the tests showed an instantaneous discharge, no matter whether warm or cold, with the exception of a 4-pin Mullard Weco-

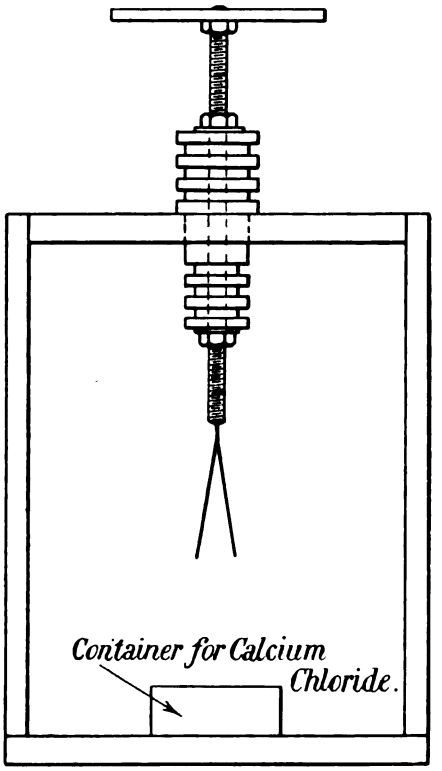

Fig. 1.

valve. This required 20 seconds for discharge when cold, but the leaves collapsed instantly after the valve had been warmed.

This unexpected result may have been due to some surplus flux spreading into contact with the grid and plate legs under the influence of the heat.*

A very odd thing was noticed with one valve, it being found that the leaves were instantly discharged when the valve was held by the glass and a leg brought into contact with the electroscope. This persisted in spite of thorough cleaning and warming followed by rubbing with silk. The glass could not be electrified.

Grid-Leak Tube.—An old-type Mullard grid-leak and condenser was tested for insulation along the containing tube. The test points were 2¾ in. apart, and the insulation was found to be as nearly perfect as one could wish.

Effect of Moisture on Ebonite.—A strip of ebonite, the insulation of which was very satisfactory, was gently breathed on. Discharge took place instantly. On testing again 10 seconds later the insulation was as good as originally.

Effect of Oil.—It was found that an oily piece of ebonite was just as good an insulator as a clean piece.

Pipe-Stem.—In order to test ebonite under very bad conditions an experiment was made with a pipe-stem. The pipe, at least eight years old, had been alight only a few minutes prior to the test, but the insulation was found to be excellent.

It seems fairly clear that either the material used for such parts as fixed condenser cases, valve insulators, valve-holders, etc., is not a sufficiently good insulator, or that there is really no need to use high grade ebonite for panels and other parts. It must be admitted that these tests do not give any idea of the actual resistance between the grid and plate legs of a valve, for example, but they do show that the insulation is far inferior to that obtained by the use of ordinary good quality ebonite.

Construction of Electroscope.

As perhaps some experimenters may wish to make up a simple electroscope, the following constructional notes are added. Anyone who goes to the trouble of making up this instrument will find it of considerable interest. A sketch of the instrument is given in Fig. 1.

Case.—This is made from a light wooden box which had a sliding lid. It measures 4 in. high by 3 in. wide by 2 in. deep inside. The bottom, sides and back are lined inside with brass foil (tin foil will do just as well) and a photographic quarter plate slides in the lid grooves and forms a window. (Any other construction will do equally well.)

*It seems possible that this may be due simply to the capacity of the electrodes, the discharge of the electroscope charging them up. A similar explanation might apply to the glass in the next paragraph.—Ed. E.W. & W.E.

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Leaf System.—This consists of about 2½ in. of 4 B.A. screwed brass rod having a thin brass strip ¼ in. square soldered into a slot cut at one end.

The rod passes through an ebonite bush (see Fig. 2) and carries a brass plate 1¼ in. in diameter at the top end, the rod being located and secured in the bush by means of brass nuts. The ebonite bush is made a push fit in a ½ in. hole drilled in the centre of the top of the box.

The gold leaves measure 1½ in. by ¼ in., and the cutting and fixing of these is the only tricky part of the whole job.

The leaf is supplied in book form, each sheet of gold being between two sheets of non-sticky paper. It is essential to purchase the loose leaf, *i.e.*, the type used by picture frame gilders. Another type is made which is useless, the leaf being stuck to the paper sheets. The writer is not an expert in handling gold leaf, but has found the best method of cutting and manipulating is as follows: Take the new book of leaf and remove the *second* leaf of gold and scrap it. Place a glass sheet in the place the leaf occupied. Cut two strips of the required size from the first gold leaf, keeping it between the leaves of paper and using a razor guided against a wooden rule or straight edge. The leaf can be seen through the paper, so that measurement is easy. Separate the strips (still between the papers) from the rest of the book, and, using a couple of needles, lift the top paper off each strip, leaving the gold leaf exposed. Moisten *each* side of the ¼ in. by ¼ in. flat piece on the rod with some *thick* varnish or adhesive and gently bring one side of the flat on to one end of one of the strips of gold leaf. The leaf will adhere at once and it only remains to lift the leaf off the lower paper strip. This will require a little coaxing and some patience. When this is done attach the other strip of gold leaf to the other side of the flat in a similar manner.

The assembly is now ready to be passed through the hole in the top of the case, during which operation the leaves must not touch the wood.

The success of the whole operation depends on the paper and leaf being cut cleanly, on care in handling, and on an absolute absence of draughts. Shorter leaves may be used if desired, as they are easier to cut and handle.

Drying.—It is an advantage if the case can be made reasonably air tight and a few small pieces of calcium chloride in a shallow watertight container in the case helps to keep the air dry and improve the insulation of the ebonite.

Charging.—The most convenient source of electricity is a piece of ebonite which has been lightly rubbed on the coat sleeve. The ebonite should be brought near the metal disc till the leaves diverge to the required extent. Keeping the ebonite in this position the disc is touched with the finger, which causes the leaves to collapse.

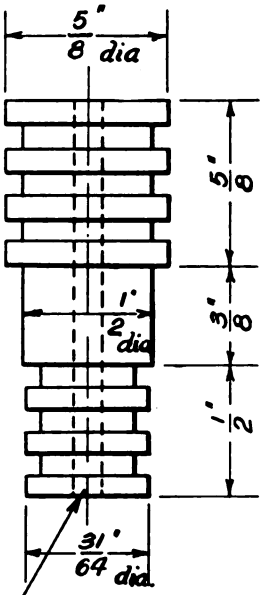

Fig. 2.

The finger is then removed and finally the ebonite is withdrawn, when the leaves will again diverge. The electroscope may be charged by bringing the ebonite into contact with the disc. This is not a good method, as the leaves may diverge so violently as to be torn away. The other method is quite safe, as the maximum divergence is under complete control.

It will be found that on bringing any conductor, no matter how perfectly insulated, near the charged electroscope, the leaves will partly collapse. This is merely due to the increased capacity of the system (the insulated conductor forming one plate of a condenser) which reduces the potential of the leaves and so their mutual repulsion.

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Radio 2FP. An Amateur Station.

By J. L. Pritchard. **[R612**

IN 1913, when FxM—the forerunner of the present station—was started, it was a spark station of 50 watts. The installation was dismantled at the outbreak of the war and subsequently lost in the archives of the Post Office. With the advent of the valve, which was largely developed during the war, it was decided to instal a continuous wave transmitter when the cessation of hostilities permitted a renewal of amateur wireless activities. The necessary permission was, unfortunately, a long time in being given.

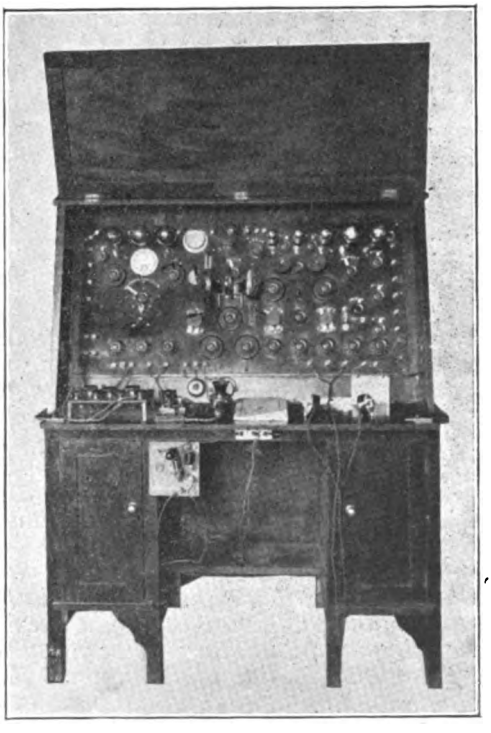

Fig. 1. *The complete transmitter and Receiver.*

It was necessary to design the transmitting and receiving sets to occupy the smallest possible space, since, owing to the shortage of houses, the new station started its being in the confined limits of a flat.

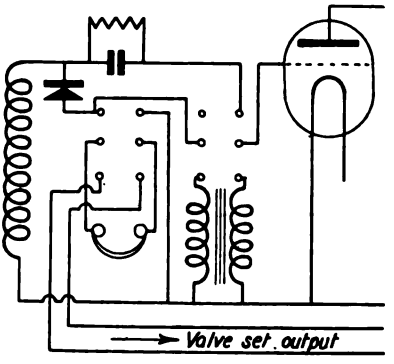

Fig. 2.

The present outfit is illustrated in Fig. 1. On the left side of the apparatus is the transmitter, which is of the Hartley type, but embodying certain modifications to suit the special requirements. The right half of the panel is devoted to the receiving part of the set. The instruments are secured on a Radion panel, sloping backwards in a wooden framework, which has a front that may be hinged over to cover the top half of the panel. This part of the installation is attached to a specially constructed table resembling a writing table, with a cupboard on either side, in which certain parts of the apparatus are housed.

Anode current is obtained from a Newton generator giving 1 000 volts. The current is smoothed by chokes and condensers, and is supplied to the transmitter in shunt. The generator is housed in the left-hand cupboard referred to above (see Fig. 1). By the cupboard is the motor-starter panel

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for controlling the generator. The tapping key is attached to the table towards the front, on which also stands a hand microphone and a pair of telephones.

The circuit diagram of the transmitter is given in Fig. 3, from which it will be seen that modulation takes place in two distinct places in the grid circuit, the two impressions being of different intensities. The major intensity takes place slightly after the impression at C_1 owing to the time lag of the electronic flow between the modulator and power valves. If the impression at C_1 is in the opposite direction to that at MV, the small impression or modulation at C_1 will form a cushion, as it were, for the larger MV modulation output. This method of modulation control has been found to give excellent results, and many reports of good reception have been received.

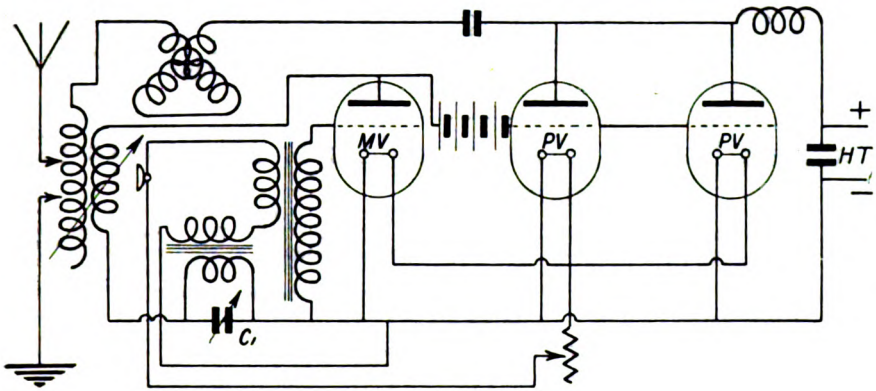

Fig. 3.

The receiving circuit employs two stages of radio-frequency, transformer-coupled amplification and two stages of L.F. amplification. Rectification is obtained by either crystal or valve as desired, by the use of switches, which also enable any combination of valves to be used. Fig. 2 shows the necessary switching arrangements for the use of either crystal or valve, from which it will be seen that the normal detecting valve is used as the first stage of L.F. amplification when the crystal is used for rectification. The telephones may also be used with the crystal detector alone if desired.

For local broadcasting, a crystal and two-stage amplifier is used, distant control from a separate room being obtained by means of a relay placed on the top of the installation and a push-pull switch. The latter is seen in the photograph on page 560, which shows the loud-speaker, which is of home construction. The size of the loud-speaker can be estimated from the Amplion "Dragonfly" seen with the larger instrument.

The relay and the accumulator which operates it are seen in Fig. 4, which shows a back view of the installation. In the top right-hand corner is the choke coil for

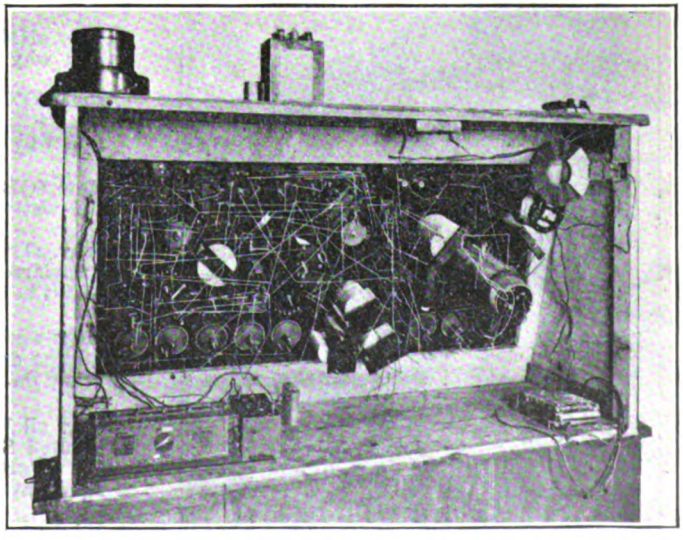

Fig. 4. Showing a back view of Fig. 1.

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smoothing the H.T. current, and below it, on the base of the framework, are the smoothing condensers. High tension batteries are placed inside the case and are seen to the left of the illustration. Filament resistances for controlling the valves are arranged in line towards the bottom of the panel. Between the groups are three variable condensers for tuning the receiving set.

As far as possible all wiring is carried out with bare tinned wire, which, in addition to improving the efficiency of the installation, adds considerably to its appearance. A feature worthy of note is the parallel arrangement of the grid connecting wires, which are seen towards the top of the panel and equi-distant from the sides. A neutralising effect is obtained by this arrangment, similar to the Neutrodyne principle, which tends to prevent self-oscillation and render the set more stable.

Things we should like to know, or points of interest to all Transmitters.

The name of the amateur who can light a Neon lamp off his stair rods when his transmitter is running ?

And what his input is ?

And why ?

* * *

The amount of the electric light bill of a well-known DX man on the southern outskirts of London ?

And why rumour has it he has to start up his high-tension generator in the afternoon ?

And if the Electric Light Company make any special arrangements ?

* * *

If Joe Fassett QSL's every QSO with England ? And why ?

The loud-speaker in use at 2FP. The small one is an Amplion "Dragonfly."

How 5BV manages to use raw A.C. on one wave-length at the same time as partially smoothed A.C. on another ?

And whether it is another attempt at "Effective Transmission" ?

* * *

If 2PC lent 8BV his bug ?

And why ?

* * *

Why 5LF doesn't put a flywheel on his generator to steady her down on key load ?

* * *

If 5RZ has dispensed with filament-heating batteries now that he uses a separate aerial for reception ?

* * *

Why a BCL should be blanked out at 50 yards range by a 100-watt transmitter when there is a difference of 265 metres in wave-length ?

And why does he complain ?

* * *

Why some "hams" morse out "yep" when "yes" would be quicker ?

* * *

Why 2NM calls "ARRRL" ?

And why some other stations call "RRLA" ?

* * *

How 5OX learnt morse ?

And if he has sold his microphone ?

And why ?

* * *

How 6QB was QSO the American 5th district on 3½ watts input ?

* * *

Why 2TK's 100-metre harmonic is louder than his fundamental ?

And if he knows it ?

* * *

Why some people like spacing waves . . . . and some don't ?

What the Post Office thinks about it ?

* * *

Why all British stations are always "QSA vy" in United States ?

Who started "es" ?

And why ?

* * *

Why was all this written ?

Why not ?

ANOTHER TRANSMITTER.

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Communication on Wave-Lengths other than those in General Use. [R800:650

A paper read by Mr. G. G. BLAKE, M.I.E.E., A.Inst.P., before the Radio Society at the Institute of Electrical Engineers on 22nd April, 1925.

AN Ordinary General Meeting was held at the Institute of Electrical Engineers, London, on Wednesday, 22nd April, 1925, Lieut.-Col. Holden presiding.

The minutes of the previous meeting were taken as read. Mr. G. G. Blake then read his paper.

Mr. G. G. BLAKE: When I accepted your invitation to give this lecture, I had intended to give you a short history of the numerous experiments which have been conducted in telegraphy and telephony on wave-lengths in the ether other than those discovered by Hertz and named after him; but in preparing the experiments for this lecture I came across so many interesting things that I now propose to touch only briefly upon the most practical systems, so that we may have sufficient time to make our demonstration as interesting as possible. In order to justify the delivery of this lecture to a Radio Society I will first show a few experiments to prove that the wave-lengths I am employing this evening are really a part of the same ether spectrum as those ordinarily employed for wireless purposes.

There are at present known to Science 53 octaves in the ether spectrum and of these our eyes are only able to perceive one octave —we are blind to all the rest. Supposing a great artist, like Turner, had been able to see all the beauty of colour present, when he surveyed some beautiful view, even his vision was so limited that he would only have been able to perceive one 53rd of the colours which may have been there.

The illustration on this page (Fig. 1) indicates the range of the spectrum. Practically all the spaces marked unknown have, I believe, since been filled in. The portions with which we shall deal this evening are those occupied by the infra-red rays, visible light, and the ultra-violet rays. I have designed an apparatus[1] (Fig. 2), in order to demonstrate that an electric spark may be the source of ultra-violet radiations (illustrated by the fluorescence of Willemite), the whole visible spectrum (viewed through a spectroscope), dark heat waves (measured by a thermometer), and Hertzian waves (which light a lamp at a distance). These various wave-lengths can be demonstrated singly or simultaneously. (A demonstration was then given.)

The condenser spark is rich in the short ultra-violet waves but deficient in long ultra-violet radiations.

A carbon arc is rich in long but deficient in short radiations.

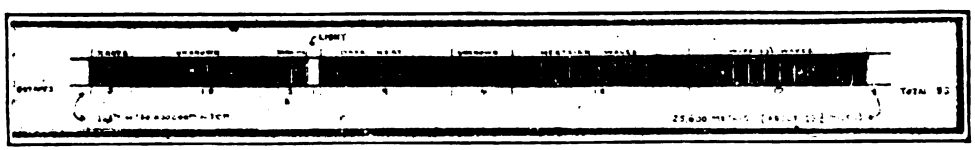

Fig. 1. *Showing the complete range of the spectrum, with its divisions.*

A tungsten arc, as used for artificial sunlight treatment, is rich in all wave-lengths; so rich that an exposure to the skin of two minutes at 18 inches from an 8 ampere tungsten arc will produce an erythema or sunburn.

A quartz mercury vapour lamp is similarly very rich in ultra-violet radiations.

The presence of ultra-violet rays in light from a carbon arc was then shown by the interposition of a "Chance" glass filter, and the fluorescence of Willemite (the ore in which zincite is found).

Zinc sulphide, Barium platino-cyanide, uranium glass, a candle, liveteeth, butter, etc., were demonstrated.

[1] This apparatus was demonstrated at the Royal Institution on 20th March, 1925.

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A couple of years ago, using an enclosed tungsten arc so screened that no visible light was present in the room, but fitted with a window of "Chance" glass through

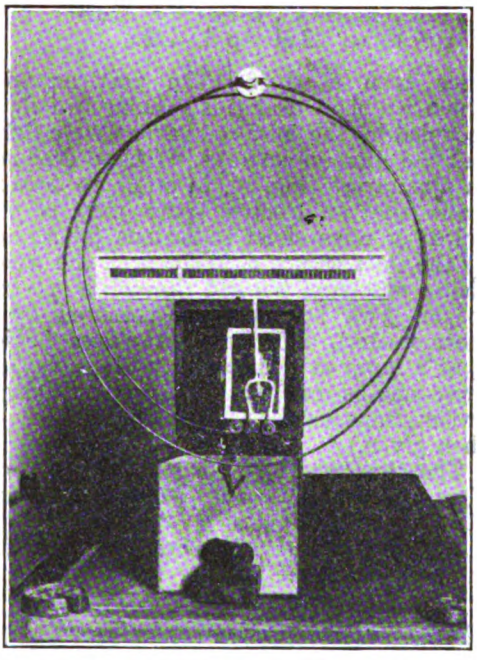

Fig. 2. *The apparatus devised to show that an electric spark is the source of various radiations.*

which invisible ultra-violet rays were projected, I succeeded in taking a photograph in a completely darkened room. As I have unfortunately broken the negative, I have for the purposes of this lecture taken another still-life group under similar conditions.

The group shown in Fig. 3 was taken by unfiltered light of a tungsten arc in ten seconds.

That in Fig. 4 was taken with room completely dark, the objects being irradiated by invisible ultra-violet rays only, all visible light being screened off by a filter of "Chance" glass (exposure five minutes).

Fig. 5 shows one taken by ultra-violet radiations only from a mercury vapour lamp with an exposure of five minutes.

A photograph taken under similar conditions, but with all fluorescent objects removed from the group, to exclude the possibility of fluorescence being in any way responsible for the results, is shown in Fig. 6.

Ultra-violet radiations were employed quite successfully during the war, both for signalling and for keeping the ships of a convoy together in their relative positions. Professor Wood gave a most interesting account of their use by the Admiralty in a lecture before the Physical Society in March, 1919. A mercury arc, of the Cooper-Hewitt type, was employed as transmitter; this was encased in a tube of "Chance" glass, which screened off its visible light and transmitted only the ultra-violet, so that at a very short distance the arc was invisible to the eye. The rays received from this arc were focused by a lens upon a screen of barium platino-cyanide, the fluorescence of which, caused by the action of the received ultra-violet radiations, could be seen when four miles away. In America, Lewis Bell and Marshall carried out very similar experiments a few months prior to the entry of America into the war, and the U.S. Army in France employed an ultra-violet signalling lamp with a fluorescent screen. Professor Wood in his lecture also described a small signalling lamp of unique design. This consisted of a 6-volt electric lamp, hidden in the interior of a telescope and so arranged that it only transmitted an exceedingly narrow beam of light, visible only to observers on whom the telescope was focused. In daylight a red filter was placed in front of the lamp so that only red was transmitted. This could not be seen at a distance, unless a similar red screen was employed to cut out the daylight; but, under these conditions, signals could be received at a distance of six miles. By night a filter of "Chance" or similar glass was used to cut out all but the invisible ultra-violet rays, and the receiving telescope was fitted with a small fluorescent screen in the focus of the received rays. This also had a 6-mile range.

Fig. 3. *Photo taken in the visible light from a tungsten arc.*

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In France, Dussaud carried out experiments with a photophonically controlled beam of ultra-violet light. At the receiving end he focused the ray upon a fluorescent screen placed in proximity to a selenium cell connected in series with a battery and telephone. Variations in the fluorescence of the former caused corresponding variations in the electrical resistance of the selenium and the transmitted sounds were reproduced in the phones.

Signalling by Visible Light.

White light consists of 7 colours: Violet, indigo, blue, green, yellow, orange and red. Each of these represents a different wave-length in the ether. When all these waves reach our eyes simultaneously, we receive the sensation of white light.

When we say that an object has a certain colour, we mean that it is absorbing all the other waves which make up the light by which it is illuminated, and it is rejecting or reflecting the colour which we see.

Here a beam of white light was passed through a prism, and its spectrum demonstrated. A barium platino-cyanide screen was held in the dark portion below the last visible violet light, and it was seen to fluoresce, thus demonstrating the presence of ultra-violet rays.

White Light.

We may now consider what use has been made of white light for signalling purposes. Heliography, or the method of signalling by the sun's rays, was in use in Algeria in the 11th century. In an article published in the *Athenæum* in January, 1882, it is stated that at that early date (11th century) many cities in Algeria communicated one with the other, in clear weather, by the sun's rays reflected from mirrors erected on the tops of high towers. In 1877 Mance devised a heliograph which was employed extensively for military purposes. Since then many others have contributed to the perfection of this form of signalling. In Algeria, French engineers have by this means (in ideal weather) succeeded in signalling over a distance of 170 miles. A record distance of 190 miles has been bridged in California. During the Boer War, General Buller heliographed to Ladysmith while it was besieged.

Figs. 4, 5, *and* 6. *Three more photographs taken of objects illuminated by radiations from various parts of the spectrum.*

Selenium.

In 1817 Berzelius, a Swedish scientist, discovered Selenium, a by-product of the manufacture of sulphuric acid from iron pyrites. Shortly after this Willoughby-Smith's assistant, May, showed that selenium would conduct electricity better when brightly illuminated than when screened from the light. Several other substances have been shown to be light-sensitive, and many types of photo-electric cells have been devised. In 1907 F. M. Jalger showed that natural antimony sulphide responded to light in a different part of the spectrum. A. H. Pfund has shown that copper oxide

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is light-sensitive. In my own experiments I have only tried selenium and a photo-electric cell kindly lent me by Mr. C. C. Paterson of the G.E.C. Research Laboratories. When using the latter, I found that too much amplification was required, the former being simpler in use, as it required less amplification. Fig. 7 illustrates the photo-electric cell.

Much work has been carried out in the construction of photo-electric cells, which can be made to respond to various wave-lengths of the spectrum, including ultra-violet and infra-red.

One of the most sensitive of these cells is that known commercially as the Thalofide photo-electric cell, invented by Case. It is claimed for this cell that its electrical resistance is reduced 50 per cent. on exposure to

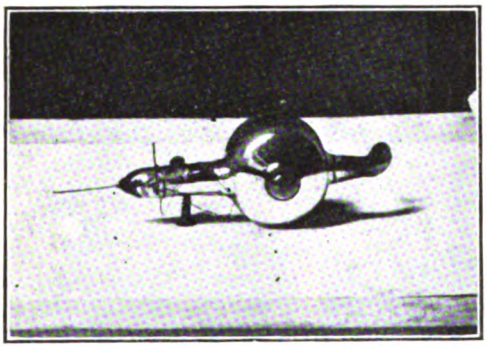

Fig. 7. *The photo-electric cell.*

light of 0·06 of a foot candle, and that its response is extremely rapid.

The Photophone.

In 1878, Graham Bell and Summer Tainter showed that a beam of light could be modulated by the sound-waves from the human voice and reproduced in a telephone, connected in circuit with a battery and a selenium cell, the latter being placed in the focus of the beam. Their researches were very comprehensive, for they actually showed no less than 50 ways in which a beam of light could be controlled by the voice. Figs. 8 and 9 show Bell's original apparatus and were made from an old illustration in "Science for All," published by Messrs. Cassell, Petter, Galpin & Co.

Fig. 10 illustrates several methods proposed by Bell for modulating the beam photophonically. (B) is a diagram of the method employed for the instrument shown in Fig. 8. (A) illustrates one of Bell's earliest methods in which the beam of light has to pass through two gratings *G* and *G*1, the former fixed and the latter movable and attached to a diaphragm *D*, so that it would vibrate in response to the voice. The modulation was said to be very poor by this method. In 1916 W. H. Bragg and A. O. Rankine patented a very perfect type of grating control which was demonstrated at the meeting of the British Association at Liverpool in 1923. (C) is a very simple method of photophonic reception shown by Bell at the 1893 Chicago Exhibition. The apparatus consists simply of a glass tube with a thin-walled glass bulb at one end, containing a fragment of charred cork. The latter expands and contracts with the very least heat changes when a photophonic beam is focused upon it, and produces corresponding movements in the column of air in the tube. These movements are heard as sound. I repeated this experiment in 1908 using a speaking arc as transmitter and found that it worked quite well over a distance of 50 yards.

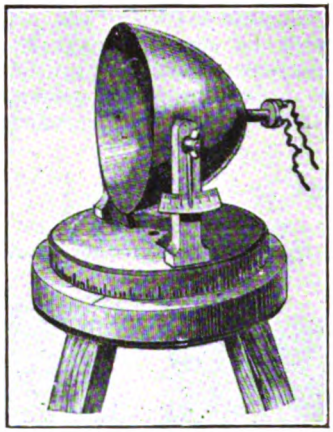

Fig. 8. *Bell's original "Photophone" receiver.*

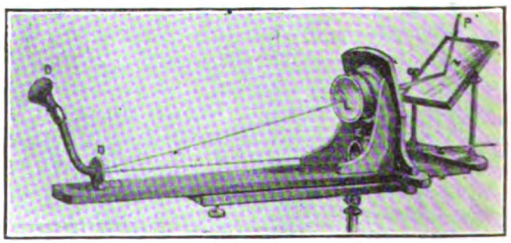

Fig. 9. *The "Photophone" transmitter.*

Mecadier successfully employed a sheet of mica covered with lampblack in place of cork, and Bell and Tainter showed that many, other substances—chips of wood, solids,

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liquids and gases—acted in a similar manner. Even the smoke from a cigar, it was stated, would in this way reproduce sounds. Diaphragms of various substances placed at the opening of a tube leading to the ears will reproduce sounds when placed in the beam of a photophone. Thermopiles, connected to a telephone, have also been employed successfully. (D) is another interesting type of receiver in which variations in the strength of the magnetic field of a small magnet NS, under the action of heat from the photophonic beam upon a thin-walled iron bulb *J*, induces currents in a winding connected to a phone *T*. In 1881 Andrew Jamieson of Glasgow employed a manometric flame as transmitter. In 1897 Bell and Hayes in America employed a speaking D.C. arc as a photophonic transmitter which they patented on 7th June of that year. And at the same time in Germany, H. T. Simon

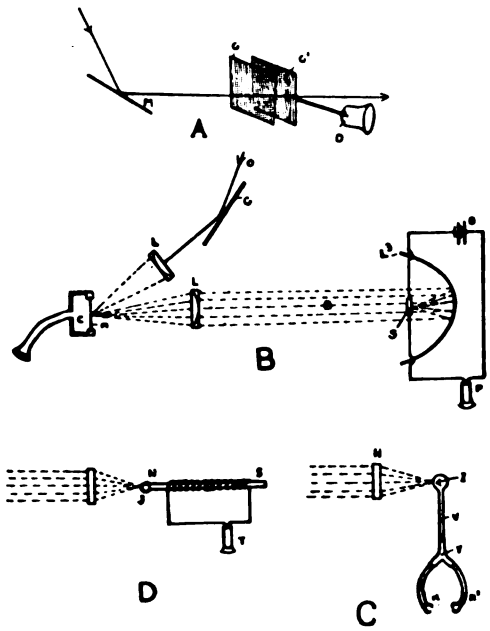

Fig. 10. *Illustrating methods of modulating a photophonic beam.*

was making quite independent experiments on similar lines which he described in a paper in November, 1897, to the Erlanger Physical Society, covering almost identical ground.

In 1900 Duddell showed another method of arc modulation which I am employing in my next experiment and will describe later.

From 1902 and during the two or three succeeding years Ruhmer, Schuckert, and several others carried out many practical experiments in photophony.

Fig. 11 shows several other methods of modulating an arc, including Simond's microphonic arc, in which the currents in an arc circuit are modulated by sound waves impinging upon the arc itself.

Fig 12 shows four methods which I have devised for modulating an arc, when coupled directly to a wireless receiving set. They all work quite well, but on the whole I have obtained the best results with that shown in the centre diagram. We will show you this arrangement working presently.

Demonstration. (A) Indirect Method.

In the case of the indirect method the sound waves from a loud-speaker

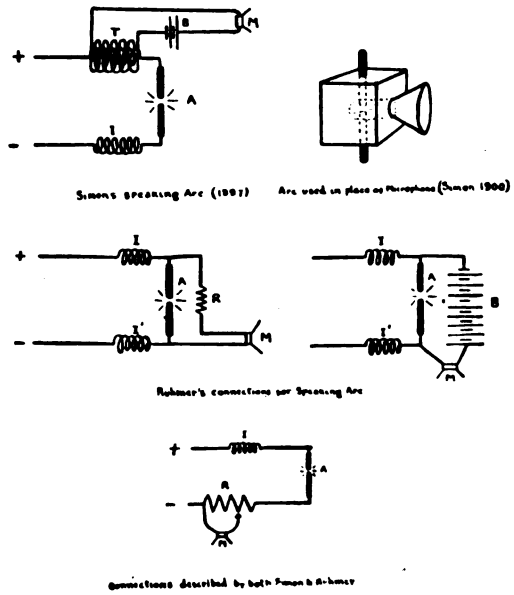

Fig. 11. *Methods of modulating an arc.*

were employed to operate a microphone connected in series with the primary of a 1 to 1 transformer and an 8-volt battery, the secondary of which was connected by the Duddell method in series with a condenser across the arc.

[At this point the photophone was shown

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in action, and speech and music from 2LO were transmitted across the Lecture Hall on a beam of light. The arc was controlled in two ways: (A) by an indirect, (B) by a direct method.]

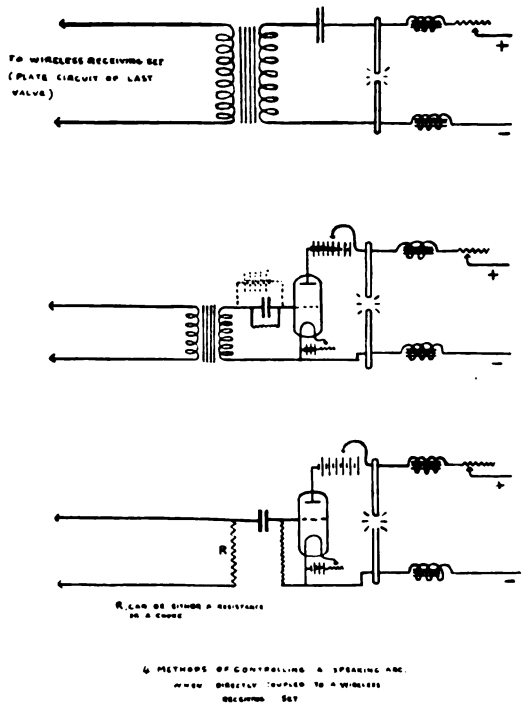

Fig. 12. *Three of the methods devised by the author for modulating an arc.*

In Fig. 13 the upper diagram A shows the connections employed. B, C, and D in the same figure show three other indirect methods which, I suggest, might be used for photophonic arc modulation, but which I have not had time to try.

(B) represents what I will call the arc blow flame method. The arc is driven outwards by a permanent magnet, as shown, and variations in the magnetism of *M* by microphone currents passing through a winding round it should modulate the arc currents.

(C) The principles of Simons' arc microphone might be employed, *i.e.*, the arc might be modulated directly by sound waves directed through a speaking tube, straight against the arc. In this case a piece of loofah should be placed in the mouthpiece. This prevents any wind from blowing on to the arc, while it allows the sound waves themselves to pass quite freely. (The use of loofah for this purpose was, I believe, suggested by Major Tucker.)

(D) is a variation of method C, in which two arcs would be coupled in series, "A" being used as a "Simons" microphone, and A1 employed as the source of the photophonic beam. The General Electric Co. have, I believe, made use of Ruhmer's Photographophone for the modulation of powerful searchlight beams. The speech-modulated light of a small photophone is recorded on a photographic film, producing variations of density on the film, which is afterwards passed across the path of a powerful searchlight beam and made to modulate the latter.

Fig. 14 represents four different methods of beam modulation which I suggest but have not had time to try. (A) A powerful light, from any source, is focused upon one

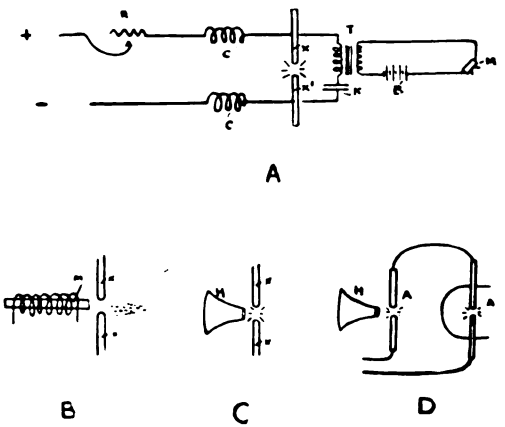

Fig. 13. *The author's fourth method of arc modulation and three others suggested, but not tried.*

end of a glass, silica, or other light conducting rod, and re-transmitted from its further end onto a parabolic mirror *M*, whence it is transmitted as a parallel beam. For signalling purposes, code signals could be transmitted by a hand-controlled shutter *K* and a musical note given to the beam either by the interposition of a revolving disc studded with holes, as used by Dr. Fournier d'Albe in his television experiments, or a little vibrator, as shown in the diagram, similar to the hammer of an electric bell, could be employed.

(B) The light might be brought to focus by means of a concave mirror and made to move more or less on or off the end of a silica rod *G*, in response to the movements

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of a diaphragm *D*, under the action of sound waves.

(C) The light might be focused upon a small sheet of glass *S*, resting against a globule of mercury at the end of a tube, the column of mercury in the latter being moved by alterations of gas pressure in the space below the diaphragm *D*. *G* is a rod transmitting the light to a parabolic reflector as before.

(D) This is another method which I think should answer quite well. The light is focused upon the end of a short length of glass tube *G* and so led to one side of a chamber *B* filled with carbon bisulphide having the same refractive index as glass, thence it is conveyed by a second glass tube G^1 to a parabolic mirror for projection.

The chamber should be very narrow, so that the globule of mercury at the end of a tube leading to a space below a diaphragm *D* is flattened fanwise and acts as a shutter, which will move up and down, and so more or less obstruct the light when sound waves impinge upon the diaphragm *D*.

Any of the four direct methods shown in Fig. 12 answer quite well, the method I showed you this evening was that illustrated in the central diagram. The currents from the plate circuit of the last valve of a receiving set were passed through a transformer and made to control a triode valve connected across the arc. The circuit (which is my own), includes a grid-condenser and leak to ensure that the valve may function at the correct point on its characteristic curve; also in addition to the H.T. supply derived from the mains there is an extra H.T. battery in the plate circuit of the valve.

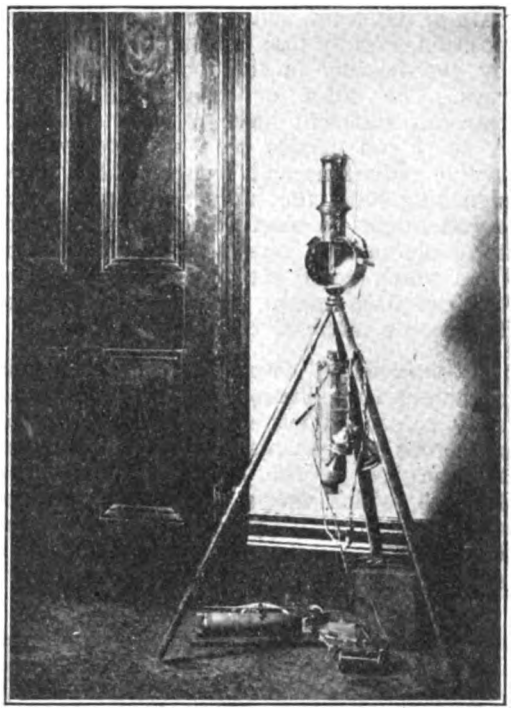

Fig. 15. *The author's speaking arc transmitter.*

Fig. 15 is a photograph of the transmitter. The speaking arc is fitted in a "Lucas" signalling lamp supported on a tripod.

Figs. 16 and 17 show my photophonic receiver. The sonoriferous beam is received by the reflector of a second "Lucas" lamp and focused upon one end of a silica rod with optically polished ends. This rod conveys the light to a selenium cell.

I have used rods of glass and silica and tubes containing carbon-bisulphide (having the same refractive index as glass).[1]

The optical instrument makers tell me that not more than 7 per cent. of the light is lost in

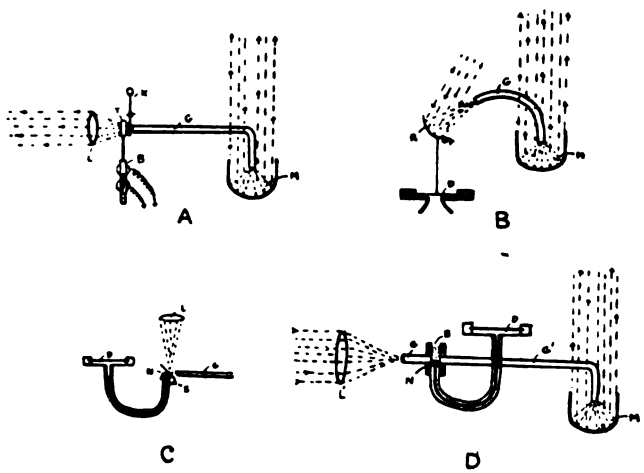

Fig. 14. *Four suggested methods for beam modulation.*

[1] Patents applied for: Nos. 6691/25 and 5801/25.

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transmission along the rods. Quite as much would be lost if the selenium cell was placed in the centre of the signalling lamp in the path of the beam, and it would, in the latter position, rapidly lose its sensitivity to light by over-heating in the focal point of the rays. The silica or glass rods do not transmit sufficient heat to affect it at all. A silica rod carries both ultra-violet and visible radiations and I suggest that when signalling with the ultra-violet rays, such a rod might be used to convey the latter to a fluorescent screen, the visible light from which would act on a selenium cell or the cell itself might have a thin layer of fluorescent material over the selenium.

I experienced considerable difficulty in obtaining amplification of the photophonically controlled current; but after trying numerous experiments I solved the problem by the use of the circuit illustrated in Fig. 18, which shows the first method of amplification that I employed, in which transformer coupling was used. *Se* is a selenium cell included in the primary circuit of a step-up transformer which controls the grid of a B.T.H. B4 valve. With this type of valve a grid bias of 16 volts gave the best results.

Fig. 16. *A photograph of the author's photophonic receiver.*

The H.T. battery gave a voltage across the selenium cell of 225 volts, and 75 volts to the plate circuit. *T* represents a pair of high resistance phones. When further amplification is required to operate a loud-speaker a transformer *F* is employed in place of the phones to connect the circuit to further stages of note-magnification. (Obviously a separate H.T. battery could if desired be employed to energise the selenium and plate circuits.) At the suggestion of Mr. Maurice Child I tried resistance-capacity coupling, which proved simpler and gave very excellent results. The circuit as I have finally fitted it up is shown in Fig. 19.

A high resistance is connected across the grid-condenser *C*; by the movement of a slider across this resistance a balance of adjustment can be obtained. The part of resistance on the right-hand side of the slider acts as a grid-leak and keeps the grid from building up too negative a charge, while that portion on the right of the slider gives the necessary voltage drop in the selenium circuit. To ensure that the grid side of the selenium cell is more positive than the negative terminal of the high-tension battery, a milliammeter which I employ in the plate circuit is not shown in the diagram. I have not conducted any long distance tests with the photophone but I have transmitted part of the 2LO programme on a beam of light from my house to that of a neighbour on the other side of the street, a distance of about a hundred yards or so, and obtained very good reception at loud-speaker strength. The circuits I have just described and demonstrated in operation require hundreds of volts of high-tension supply.

I will now show you a circuit I have devised[1] in which a selenium cell controls the grid of an oscillating valve. This arrangement requires only the use of a 60 or 75 volts H.T. battery. (I have had it working on 15 volts H.T.)

It can be employed by itself when the coupling between the grid and plate circuits is tight, and it is oscillating at audible

[1] Patent applied for: No. 9305/25.

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frequency, or it can be oscillated at radio-frequency and used to heterodyne with any

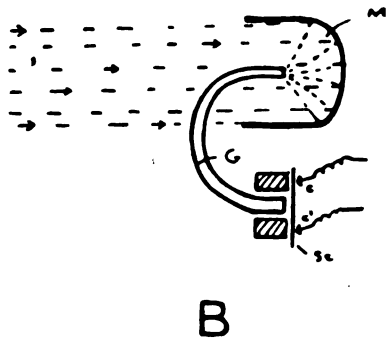

Fig. 17. *The principle of the receiver.*

ordinary receiving set using reaction. In the latter case an enormous increase in sensitivity is obtained in addition to any required degree of amplification. This arrangement is so sensitive that the light from a distant hall lamp from a house 50 yards or more away is ample, when allowed to fall upon the selenium cell, to give an appreciable change in the beat note.

Fig. 20 shows the selenium cell in the grid circuit of the valve; but I find it can be placed across the inductance or across the reaction coil or between the grid and reaction circuits, in almost any position. The cell can be placed between the grid and the leg of the filament in place of an ordinary grid-leak; but I find that owing to its exceedingly high resistance it is best to connect it to a more positive point on the H.T. battery and so adjust the valve to function at the most suitable point on its characteristic curve.

[Here a demonstration was given and the sensitiveness of the circuit was shown in the following ways:—

(1) Heterodyned with a receiving set.
(2) By itself when oscillating at an audible frequency.]

The circuit, it seems to me, is capable of a good many applications, including the following:—

(*a*) For cable telegraphy it might be operated by very minute movements of light from a mirror galvanometer and the beat note could cause a suitably tuned reed, placed at the orifice of a resonant tube or cylinder, to respond and operate a relay. Considerable selectivity could be thus obtained and by use of a plurality of such cells, etc., a number of messages might be transmitted, each on a different note-frequency. All the notes could be produced simultaneously in a loud-speaker and each one separately recorded by its own suitably tuned reed relay and recording instruments.

Alternatively the relay might be arranged directly in the plate circuit of the receiving valves.

(*b*) To indicate the transit of a star across the field of view of a telescope. In this case the selenium or other light sensitive cell would be arranged at the eyepiece of the telescope. Dr. Fournier d'Albe has already used selenium cells in another way for this purpose; he is here this evening and I hope, Mr. Chairman, you will be able to prevail upon him to describe his experiments to us in this direction.

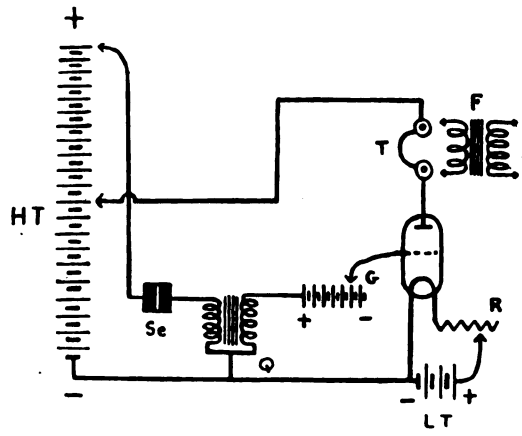

Fig. 18. *The circuit diagram of the first method of amplifying the photophonic current.*

(*c*) On board ships in the vicinity of a lighthouse, such an arrangement would give a loud signal or change of note, when the beam of light from the latter passed across the field of view of the cell.

(*d*) For photometric purposes, standardisation of candle-power, etc. In this case a self-luminous screen coated with radium paint might be employed as a standard.

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(*e*) The comparison and measurement of quantities or radiations of radium or other radio-active substances by measurement of the fluorescence of the fluorescent screen exposed to the radiations therefrom, and their effect on a selenium cell.

(*f*) The transparency of an object to light or other radiations could be compared.

(*g*) The density of various patients' bodies to X-rays could be measured with a view to ascertaining correct exposures in radiography.

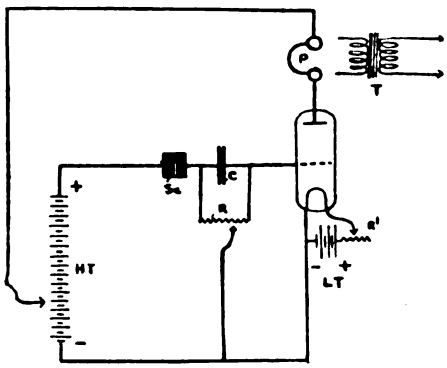

Fig. 19. *Showing the finally adopted circuit.*

(*h*) For naval, military and police purposes such a circuit, suitably disguised, could be placed in proximity to a light at a distance from a camp, building or ship. The circuit being employed as a transmitter would be picked up and caused to heterodyne a wireless set at the camp. This arrangement would then act as an invisible sentry. If anyone came between the light-sensitive cell and the light or tampered with either, his presence would be indicated by a change of note.

(*i*) This method might also be applicable in methods of distant control of airships, torpedoes, etc.

(*j*) Another possible application would be on the road at dangerous corners to give a loud howl when a motor passes and so give warning to motorists of dangerous corners.

(*k*) It might also find application in systems of television.

(*l*) For heliographic and other forms of light signalling.

(*m*) In methods used for assisting the blind to realise the presence of light, etc.

In cases *c*, *h*, and *j*, the interfering effect of a rising moon or other unwanted light could be balanced out by the employment of two selenium cells in different arms of a Wheatstone Bridge, the light acting equally and oppositely upon them both and thus balancing out its effect; the control beam would, of course, only be directed on to one of the cells.

Infra-red Rays.

We now come to waves longer than visible light in the region of the spectrum between visible light and Hertzian waves.

L. A. Charbonneau applied for a British patent in 1920. His idea was to make use of the fact that infra-red radiations rapidly quench fluorescence. A small screen of green zinc sulphide, wrapped round a cylinder or drum, was kept in a state of mild fluorescence by slow rotation in front of a small light, itself hidden from the observer behind the drum. The infra-red rays used for signalling were allowed to fall upon the screen, and each signal would cause a dark patch to appear where it destroyed fluorescence. The signals could be read by eye or photographically recorded. At the transmitter the visible light from an incandescent filament lamp was cut off by a filter of specially prepared black glass.

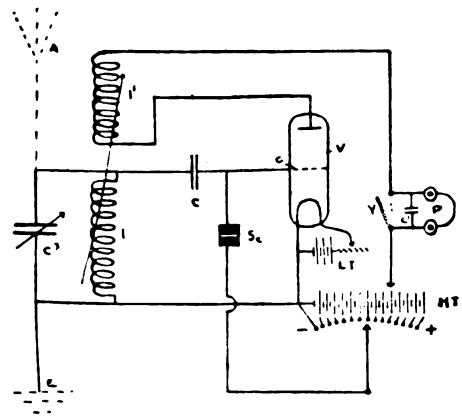

Fig. 20. *Illustrating how the selenium cell is incorporated in the grid circuit.*

Several other workers have developed methods of signalling employing infra-red radiations but time will not permit us to go further into the subject this evening.

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The Discussion.

Dr. E. E. FOURNIER D'ALBE: I have been exceedingly interested in Mr. Blake's prolific and fruitful discourse on many methods of signalling on wave-lengths in the ether other than those ordinarily used and I congratulate him upon it, and upon giving us a very interesting contribution to our Proceedings. He made one slight slip when he said that Berzelius discovered selenium in 1871; it should be 1817, but it is remarkable to think that between 1817 and 1871 the remarkable properties of selenium remained undiscovered, and when they were discovered they were regarded as a bit of a nuisance because high resistance was wanted in the cable stations and selenium was found to be useless for the purpose because it changed its resistance during sunlight. Mr. Blake showed us a new method of producing a change of note. I did not quite hear how this change of note is affected by slowness or rapidity of intermittence, but I should judge that when the emissions are slow, the change of note is rather greater than when the emissions are more rapid. That is a thing I am particularly interested in, because theoretically the amount of difference between the lower and the higher note should be in exact proportion to the length of exposure. Thus, we might get an interval of a semitone when experimenting at second intervals and, say, one-third of a semitone if the rate is accelerated three times. In this experiment very minute quantities of light are involved, but I think it is quite sound to believe that, used judiciously, selenium is a great deal more sensitive to light than the human eye, and that is saying a great deal because the human eye is sensitive to an extraordinarily small amount of energy, I believe about 30 quanta per second, so that if this new heterodyne circuit is used we might find that with light of very low intensity we might get an intermittent effect due to the fact that we had got down to single quanta. That seems to offer a very interesting contribution to the theory of the general constitution of light. The controversy about the quantum theory is still raging, and it may be that we are at last in touch with the real crucial experiment to decide whether light has a structure or not, whether it comes in lumps or a steady stream. As regards the stars, there are methods of making stars audible without amplification, It was done in the case of Aldebaran about ten years ago and I was interested to hear that Mr. Blake now has this quick and ready method of using this change in note. As a rule, when you rely on the steady effect of selenium you have to wait some time before it comes into full force. I am entirely with Mr. Blake in saying that so far as we know at present only intense light can be made really useful. This is due to the fact that we cannot use dim light with any real effectiveness on account of the very small energy which we can obtain in that way. If this new method could be used with rapid emissions it would have the advantage that you would get an instantaneous effect when you use rapidly intermittent light. As regards the use of this method for giving warnings, I can quite understand that it would be useful for burglar alarms and motor car purposes. Especially can I see a very valuable field for it for burglar alarms in America, where it should find a most remunerative field of application, because in New York and one or two other places burglars are very rife just now. Generally speaking, I have been extremely interested, because Mr. Blake has thrown out quite a number of new methods and I think probably they are very promising, at any rate all with the exception of the one with mercury, because I think that tube of mercury would have too much inertia to follow the rapid fluctuations of speech. Nevertheless, they all ought to be tried and I think it is very kind of Mr. Blake to give these suggestions to the world because any one of them might be very valuable to himself. I am sure we must thank Mr. Blake for his lecture.

Admiral Sir HENRY JACKSON: I should like to add my congratulations to Mr. Blake for his interesting paper and the valuable suggestions contained in it. There are a great many points of ingenuity in it to which we are indebted to him. I think bending the ray round the corner is rather a good idea and altogether the paper has given us plenty to think about. Mr. Blake has also shown us that wireless waves are not the only means of communication through the ether.

Mr. F. H. HAYNES: I have no observations to make on the extremely interesting subject to which Mr. Blake has devoted his attention. He has shown what can be done with very short ether waves; we are getting down now to waves as short as 20 metres, but we have no idea as to what may eventually be achieved with ultra-violet and infra-red waves at the hands of the wireless amateur.

Mr. Blake has outlined several microphonic methods and has shown us their application in wireless communication by means of the selenium cell. His work is full of suggestions and in the application of the selenium cell with reasonably low resistance to wireless circuits we have a new field to work in, particularly in regard to telephony. We certainly must thank Mr. Blake for having opened up what is an entirely new field.

Mr. BLAKE: Before I reply to the questions that have been raised I would like to thank those who have helped me this evening. I have had a great deal of help from Mr. Child, who took the trouble to bring all his receiving apparatus here and undertook to receive 2LO and relieve me of all the trouble of getting the signals from Selfridge's. I also wish particularly to thank Dr. Fournier d'Albe for lending me an unlimited supply of selenium cells. He told me that I could have any cells that I wanted and he has been most kind in helping me in that way. Mr. Patterson also very kindly lent me a photo-electric cell which I used in my experiments. I also must thank my assistant, Mr. Pickering, for assisting me to prepare these experiments and I think I also ought to thank the lanternist for working the slides. Dr. Fournier d'Albe pointed out the slip I made with regard to the date of the discovery of selenium. Of course 1817 is the date. Then he raised the point with regard to the change of note not corresponding quite to the rapidity of the light change. I am afraid I am not sufficiently musical; in fact I am not at all musical and am not able to appreciate these half tones and fine differences. I wish somebody else who is musical would speak on this point after what they have heard this evening, because I am afraid

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I am not able to appreciate it. Then he spoke of the controversy between the quanta theory and that of the undulatory theory of light and suggested that my experiments might prove very valuable. I am very glad he raised that point and I hope somebody will take it up and carry it forward as a serious investigation. With regard to burglar alarms, I am afraid I am not altogether with Dr. Fournier d'Albe, because I can foresee that in place of the loss that we might get through burglaries, our money would go to the makers of high tension batteries, etc. I am afraid also that I am not quite so unselfish as Dr. Fournier d'Albe represented, because I have taken the precaution to patent several of the circuits that I have shown this evening. I do not think there is anything to reply to in the remarks of Admiral Sir Henry Jackson nor those of Mr. Haynes.

Captain L. F. PLUGGE: I should like to propose a hearty vote of thanks to Mr. Blake for his most interesting lecture. It is certainly a most important thing to know that there are vibrations in the ether which we can make use of in the manner he has suggested which are quite different from the wireless waves that we have been working with for so long.

Mr. GREENWOOD WATKINS: I have pleasure in seconding the proposition. I have listened with very great pleasure indeed to Mr. Blake's lecture and I am sure we have all benefitted from what he has told us about the various circuits and the use of radiation in such an unusual way.

The vote of thamks was carried with acclamation.

Mr. CHILD (who was in the Chair, Lieut.-Col. Holden having left): Before I close the meeting I should like to mention that we have had with us to-night some representatives from the States who have come over recently to attend the Conference in Paris. I should like to say to them on behalf of the Radio Society of Great Britain how very much we welcome them and hope they will go away with a better understanding of matters radio, as they occur in this country. On behalf of the Radio Society of Great Britain we welcome our friends from the States and are very pleased to see them.

The meeting then closed.

R.S.G.B. Transmitter and Relay Section Dinner. [R545·06

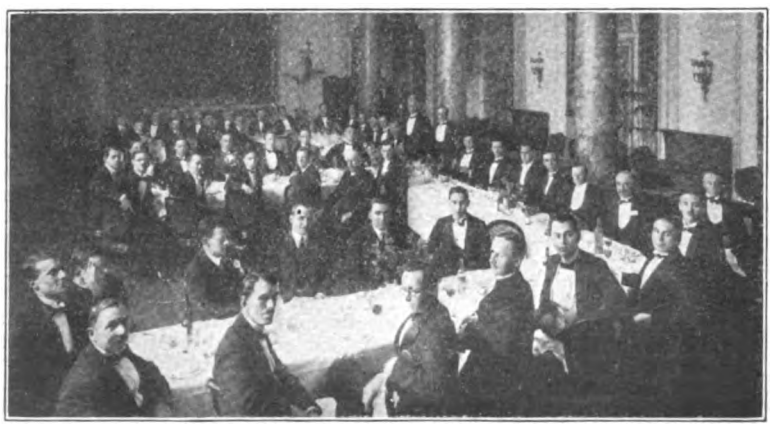
A VERY successful dinner, which served the dual purpose of honouring distinguished foreign guests who had attended the recent Paris Conference and laying the foundation of the International Amateur Radio Union in Britain, was held at the Waldorf Hotel on 24th April. Mr. H. Bavin-Swift, Chairman of the Transmitter and Relay Section, presided, and the guest of honour was Mr. Hiram Maxim, President of the American Radio League. Mr. Maxim, replying to the toast of the I.A.R.U., proposed by Mr. Marcuse, emphasised the serious work of amateurs at the Conference at which, he said, twenty-three nations were represented. He pleaded for a spirit of wide tolerance on the part of amateurs who were perhaps sometimes as intolerant as the early Puritans. "Remember," he said, "that we amateurs who are interested in the scientific side of two-way communication must be tolerant and reasonable. Given unanimity, nothing can hold us back, but unanimity can only be attained through a spirit of tolerance.

Mr. Kenneth Warner, Secretary of the A.R.R.L., returning thanks for the cordial reception he had met with in England, said that for a long time past Americans had taken a keen interest in English developments and now looked forward to regular talks. "It is," he said, "a very great pleasure to meet in the flesh the friends made through the medium of the ether." America was looking forward eagerly to the day when every citizen with his own home-made set would be able to communicate with friends in any part of the world. This would be a great step towards the promotion of international understanding.

Canada, France, Newfoundland and other countries were represented among the fifty-two members and visitors present and even Mesopotamia had its ambassador in Captain Durrant, who, in a delightfully humorous speech, explained how, with no gear and only junk available, he had constructed a short wave station in the desert and had established communication over a distance of 3 000 miles.

After dinner, Mr. Marcuse invited those interested in the formation of a British Section of the I.A.R.U. to confer and give in names. It has since been stated that 40 members have joined and that 50 per cent. of this number were recruited at the dinner. Mr. Simmonds (2OD) has been elected the first President of the British Section of the Union and, for the time being, Headquarters will be in Connecticut and the organisation of the A.R.R.L. and the Journal *Q.S.T.* will be at their disposal.

Our photograph shows Mr. Maxim standing on the right of the Chairman.



A Photograph taken during the Waldorf Hotel Dinner.

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Testing Accumulators.

[R800: 621·354.

IT is perhaps not very widely known among the general public that in recent years a rather important advance has been made in the methods of testing the state of accumulators.

We think that it is fairly widely realised by now that the voltmeter, as usually applied, is quite useless as an indication of whether a battery is charged or not, and the use of the hydrometer is increasing. While, however, the hydrometer gives a particularly good estimate of the state of charge of the battery, it gives comparatively little information as to the condition of the plates. In order to get information on this heading, the usual requirements hitherto have been not only a hydrometer, but also a voltmeter and lastly considerable experience.

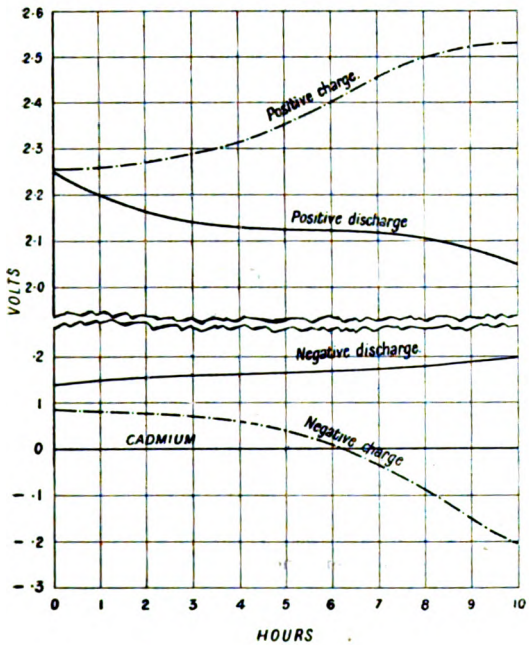

Fig. 1.

The new method, however, of which we speak, simplifies matters considerably, for it enables one to get definite information as to the state of the positive plates and the negative plates separately. This is achieved by placing in the electrolyte a third temporary "plate" of a definite unchanging material, and measuring the voltages between this third plate and the existing negative and positive plates of the battery. After various investigations as to the most satisfactory material for the third plate, it has been found that cadmium metal is the most satisfactory: the surface of the cadmium is allowed to become slightly sulphated, which is achieved by keeping it when not in use in a pot of acid. The cadmium "plate" is in the form of a small rod covered by a perforated ebonite tube to prevent it from actually touching the positive or negative plates, and is attached to a flexible lead. This is shown in Fig. 2.

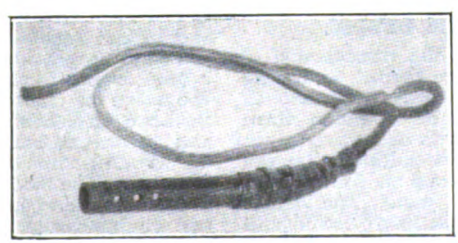

Fig. 2.

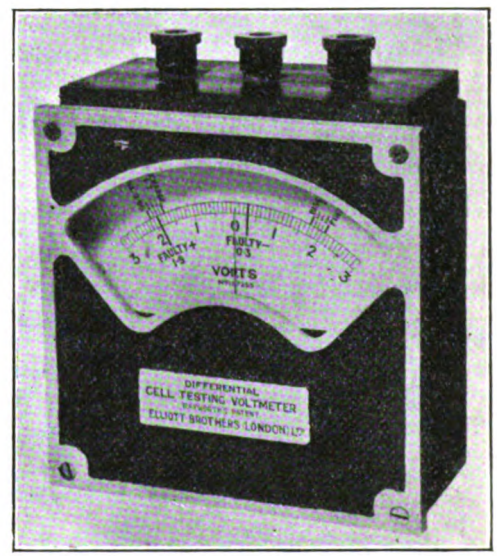

Fig. 3.

It is not necessary that it should be completely immersed in the electrolyte, and in the case of ordinary small wireless batteries it is simply inserted through the vent plug of the cell, making sure that at least the tip is below the top of the acid.

Fig. 1 shows the voltages that may be expected between the cadmium electrode and the accumulator plates in various states of the battery (it should be noted that the readings are to be taken while the current is actually flowing). In this diagram the voltage of the cadmium electrode itself has been taken as zero, and it will be seen that during discharge the negative plate becomes more positive

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with regard to the cadmium, the voltage between them rising from 0.14 to 0.2. During charge the reverse takes place, and towards the end of the charge the negative plate falls below the cadmium electrode in voltage, the difference being rather more than 0.2. The voltage between the positive plate and the cadmium electrode moves in the opposite direction, falling from 2.25 to 2.05 during discharge, and rising from 2.25 to near 2.5 on charge.

It is obvious that the difference between these two voltages, *i.e.*, between positive to cadmium and negative to cadmium, represents the actual voltage of the cell itself. Therefore it is obvious that if the total voltage of the cell is irregular, an examination of the two separate voltages from the plates to the cadmium will show which of the accumulator plates is at fault, and thereby gives definite information which can be obtained in no other manner.

It is, of course, possible to use a cadmium electrode of this type on an ordinary voltmeter, but it should be noted that a first-class meter must be used, *i.e.*, one of high resistance and with an even open scale. Messrs. Elliott Bros. (London), Ltd., Century Works, Lewisham, S.E.13, have now produced a special voltmeter for the purpose, the scale of which is marked over the range of positive plate voltages with special indications showing the state of discharge of the battery. Special marks are also placed on the scale showing the danger voltages, below which a positive plate is in bad order or above which the negative plates need attention. Fig. 3 shows this voltmeter as now being produced, while Fig. 4 shows detailed curves of all three voltages in a particular case, these latter having been supplied by Messrs. Elliott Bros. It should be noted that the voltmeter itself is covered by patents and is known as the "Rayworth" differential cell testing voltmeter.

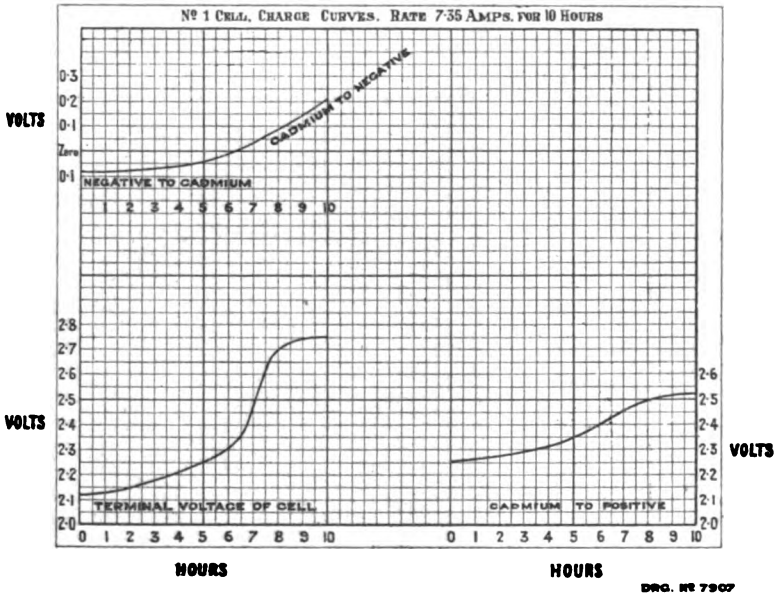

Fig. 4

THE AIRMAX COIL.

In our last issue, when referring to the Airmax Coil, it was mentioned as being manufactured by Messrs. Airmax, Ltd., of Sheffield. It has been brought to our notice, however, that J. Dyson, 5 & 7, Godwin Street, Bradford, is the sole concessionaire for this piece of apparatus.

SHORT WAVES FROM BERLIN.

Interesting experiments on the transmission of short wave-length signals were carried on during May by the Telegraphentechnische Reichsamt in Berlin. Transmission was made in morse three times a day all through the month on a wave-length of 54 metres. The signals were broadcast for twenty minute periods from 2 until 2.20 p.m., from 6 until 6.20 and from 10 until 10.20 p.m. The signals were composed of groups of six morse letters and intervals of eight seconds alternately. The first of these experiments took place on 1st May, at 2 p.m.

A COURSE OF VALVE LECTURES.

"The Thermionic Valve and its Uses in Wireless Circuits" is the subject of an interesting series of six lectures being given by Captain W. H. Date, B.Sc., at the Regent Street Polytechnic Institution. The first and introductory lecture was delivered on Tuesday, 19th May, at 6.30 p.m. All the lectures will be given on Tuesdays (with the exception of 2nd June) at the same hour. The syllabus indicates that a wide field is being covered, from a brief outline of the electron theory to the use of the valve in transmitting and receiving circuits. Such a course should be of interest to all amateurs, and in some cases might serve to clear away haziness on certain points of the work valves are capable of doing. The modest fee of 7s. 6d. for the course, brings it within easy reach of all. The apparatus and equipment of the wireless laboratory of the Polytechnic will be available for the demonstrations and experiments given in the course of the lectures.

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Directional Properties of Receiving Aerials.

By R. L. Smith-Rose, Ph.D., M.Sc., A.M.I.E.E., and R. H. Barfield, M.Sc., A.C.G.I. **[R115**

Describing some experiments from which were obtained definite equations for determining the relations between the orientation of the receiving aerial and the resulting signal strength.

EARLY in the development of wireless telegraphy it was discovered that certain types of receiving antenna possessed directional characteristics, *i.e.*, that the amount of energy picked up partly depended on the orientation of the various parts of the aerial with regard to the transmitting station.

The simplest form of directional aerial is the inverted "L" aerial, which consists of a horizontal length of wire with a vertical down lead at one end. It was found by Marconi and others that an aerial of this type was most efficient when erected so that its horizontal length was in the line joining transmitter and receiver, with its free end pointing *away from* the transmitter; while it was least efficient with its horizontal length in the same direction but with its free end pointing *towards* the transmitter. (See Fig. 1.)

The existence of this property has been definitely proved by a number of experiments, the most important of which are probably those of Prof. Fleming,[1] carried out in 1906, who drew a number of characteristic polar curves for various aerials, and showed that the effect was of considerable importance with the particular wave-length and aerial dimension with which he was working. At a much more recent date the directional effect is seen in its most extreme form in the Beverage Antenna,[2] in which everything is done to enhance its value.

The practical question now arises: to what extent is the directional effect of importance in the common types of aerial in use at the present day, such, for instance, as a simple broadcasting receiving aerial?

As far as the authors are aware, this question has not hitherto been satisfactorily answered in any published work, with the result that at the present time there exists a considerable difference of opinion as to whether or not it is worth while to make the most of the directional properties of a receiving aerial. Thus from the experimental work on the subject already referred to it is not possible to draw any general conclusion valid for the most common forms of aerial and wave-lengths at present in use; nor is there any simple theoretical formula existing which can be employed for the determination of the directional characteristics of aerials.

It is therefore the object of the investigation described in this article to provide the answer to this question; that is, to determine, both experimentally and theoretically, the directional properties of aerials under as widely varying conditions of dimension and wave-length as possible.

I.—Theoretical Considerations.

We shall first attack the problem from a theoretical point of view. When a wave

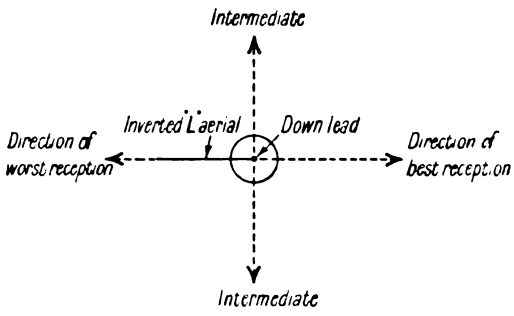

Fig. 1.

travels over the surface of the earth its front is not perfectly vertical, but, owing to a sort of dragging action of the imperfectly conducting earth on the feet of the waves,

[1] "On the Electric Radiation from Bent Antennæ." J. A. Fleming, *Phil. Mag.*, 1906, page 588.

[2] "The Wave Antenna." H. Beverage, C. Rice and E. Kellog, *Jour. Amer. Inst. Elect. Eng.*, 1923, pages 258, 372, 510, 636, 728.

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the front is inclined to the vertical at a small angle. (See Fig. 2.) Zenneck has pointed out that this phenomenon provides a simple explanation of the directional characteristic of aerials; for, in such a wave, the electric force has a horizontal component in the direction of transmission which will act on any horizontal conductor placed in that direction, such as the horizontal top of an inverted "L" aerial.

If, then, the aerial is directed with its free end towards the transmitter, the horizontal and vertical components oppose; if in the opposite direction, they assist. This is shown clearly in Fig. 3. Thus the aerial should be a better receiver in the latter position than in the former, which, as already indicated, is what is actually found by experiment to be the case.

Accepting the above explanation as the correct one, we will attempt to use it as a basis for the quantitative determination of the degree of directivity of an aerial.

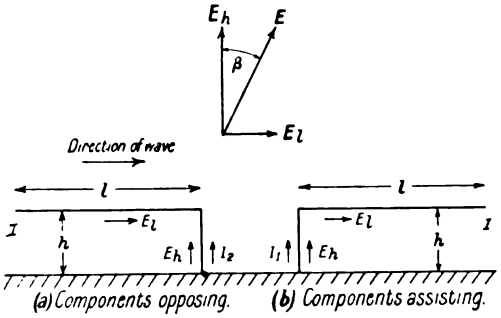

Fig. 3.

First of all it is necessary to have some definition of the quantity we are trying to determine. The strength of signals obtained from a given aerial depends on what is known as the aerial current, that is, the current in the aerial at a point near the earth; we may therefore conveniently define the directive effect of an aerial as the difference in the aerial current obtained by rotating a given aerial from its least favourable to its most favourable position, this quantity being expressed in terms of the average value of the two currents. Thus, if I_2 be the aerial current when the aerial is pointing towards the transmitter (Fig. 3), and I_1 the current when it is pointing in the opposite direction, and we call the directive effect D, we have:—

$$D = \frac{2(I_1 - I_2)}{I_1 + I_2} \quad .. \quad .. \quad (1)$$

Let l = horizontal length of aerial;
h = vertical height of aerial;
E = field strength at receiver;
β = angle of inclination of wave front to vertical.

Then for the E.M.F. in the horizontal portion we have: $E_l = El \sin \beta$, and for the E.M.F. in the vertical portion $E_h = E_h \cos \beta$. Each of these E.M.F.s will produce at the foot of the aerial a certain current proportional to that E.M.F., so that the total aerial current will be the resultant of two currents given by

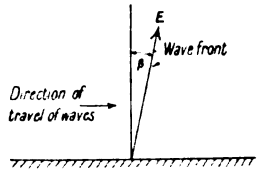

Fig. 2.

$$I_h \text{ (due to } E_h) = K_h E$$
$$I_l \text{ (due to } E_l) = K_l E,$$

where K_h will not be equal to K_l, since the aerial current is not the same at all points of the aerial, but falls off along its length. Hence, for the total aerial current at aerial foot in the two respective aerial positions (most favourable and least favourable):—

$$I_1 = I_h + I_l \text{ (E.M.F.s assist, Fig. 3}b\text{)}$$
$$I_2 = I_h - I_l \text{ (E.M.F.s oppose, Fig. 3}a\text{)},$$

or, substituting values of I_h; I_l; E_h; E_l,

$$I_1 = E\,(K_h h \cos \beta + K_l l \sin \beta)$$
$$I_2 = E\,(K_h h \cos \beta - K_l l \sin \beta)$$

and $I_1 - I_2 = 2EK_l l \sin \beta$
$I_1 + I_2 = 2EK_h h \cos \beta$

Hence

$$D = \frac{2(I_1 - I_2)}{I_1 + I_2} = 2\frac{K_l}{K_h} \cdot \frac{l}{h} \tan \beta \quad .. \quad (2)$$

We will take the various factors in the right hand side of this expression in turn:—

(A) l/h — the ratio of the horizontal length to the vertical height is obtainable by direct measurement.

(B) In practice the determination of $\tan \beta$ is complicated by the fact that the angle of inclination of the wave-front (β) actually suffers a periodic variation during each cycle of the advancing wave; in other words, the electric field is elliptically polarised in the vertical plane through its direction of travel. Fortunately, however, this effect is sufficiently small in most practical cases to be ignored when considering the directional properties of aerials, and we can obtain a very good approximation by assuming the field to be

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linear and inclined at a fixed angle β, as depicted in Fig. 2, unless we are dealing with very short waves or with ground of abnormally high resistance.

This angle (β) can be measured by direct experiment by means of a rotating rod aerial, or it can be calculated if the value of the conductivity of the earth at the receiver is known. Thus it can be shown from simple electro-magnetic theory that the relation :—

$$\tan \beta = \frac{1}{2}\sqrt{\frac{n}{\sigma}}, \quad .. \quad .. \quad (3)$$

where σ = conductivity of earth in E.S.U. and n = frequency of received waves, holds good as a close approximation as long as β remains small.

In some recent experiments conducted by the authors, the conductivity of most typical kinds of soil to be found in England was determined. It was found that the value of the conductivity for each locality did not differ greatly from 10^8 E.S.U. and was not appreciably affected by the degree of humidity near the surface. It may thus be fairly safely concluded that this can be taken as a representative value for the majority of localities in England; although in an exceptional place, where the ground was quite dry to a great depth, it would undoubtedly be much smaller. We therefore see that $\tan \beta$ is a determinable factor.

(c) The remaining factor is the ratio K_l/K_h. K_l, as we have seen, gives the relation between the E.M.F. induced in the horizontal portion of the aerial and the current produced by that E.M.F. at the *foot* of the aerial; and K_h is a similar constant for the vertical portion of the aerial. These constants are unfortunately very difficult to calculate, as a complete knowledge of the current distribution in the whole aerial system is involved. The attempt to determine the directivity of a given aerial from simple theoretical considerations alone therefore breaks down unless we are prepared to plunge into an elaborate mathematical analysis of aerial current distribution.

II.—Experimental Determination of Directivity.

It was therefore decided to attempt to determine "D" by experiment. The basis of the method was to measure by means of a "radiogoniometer," as used in the Bellini-Tosi system of direction-finding, the ratio of the currents induced in two aerials of identical dimensions but of which one was pointing directly towards the transmitting station and the other directly away from it. The arrangement is shown in Fig. 4.

The radiogoniometer consists of two field coils F_1 and F_2 with axes at right angles to each other, with a coupling or "search" coil "S" which can rotate within the space enclosed by the two field coils, thus varying the coupling between each of the field coils and the search coil in such a way that when the coupling attains a maximum value for one of them, it is zero for the other. The search coil is provided with a pointer and scale graduated in degrees. One of the field coils is connected in the earth lead of each of the aerials, which are left untuned.

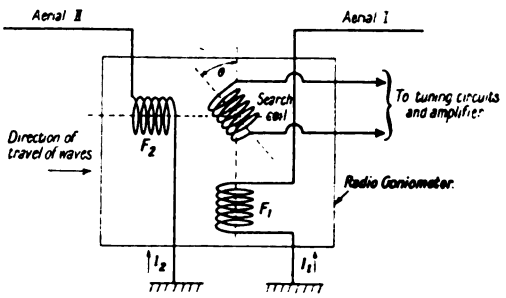

Fig. 4.

The search coil was connected to the tuning circuit and amplifier of the receiver.

The method of operation (having adjusted the receiver so that the required transmitting station can be heard) is to rotate the search coil until a position is found when the signals vanish or pass through a minimum. If, then, the search coil makes an angle θ with this field coil F_1 in this minimum position, and I_1 be the current through this coil while I_2 is the current through F_2, it can very simply be shown that :—

$$I_1/I_2 = \tan \theta.$$

The apparatus thus provides a very convenient method for comparing the currents in the two aerials. If the aerials were non-directional we should, of course, find that $\theta = 45°$; because $I_1 = I_2$, so that $\tan \theta = 1$. If they are directional and aerial I is oriented most favourably, I_1 is greater than I_2, so that we should expect to find $\theta > 45°$. In

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practice this was always found to be the case, giving an experimental proof that an aerial pointing away from a transmitter is more efficient than an aerial pointing towards the transmitter. But we require more definite information than this. We have defined the directivity D of an aerial by means of the relationship.

$$D = \frac{\text{Current Difference}}{\text{Current Average.}}$$

$$= 2\,\frac{I_1 - I_2}{I_1 + I_2}$$

$$= 2\,\frac{I_1/I_2 - 1}{I_1/I_2 - 1}$$

$$\therefore\ D = 2\,\frac{\tan\theta - 1}{\tan\theta + 1} \quad \ldots \quad \ldots \quad (4)$$

so that from a measurement of the angle θ we are at once able to obtain D from Equation (4).

A great part of the success of the method depended on the ability to erect two aerials identical as to their electrical properties. For this great care had to be taken in ensuring equality of the aerials' dimensions and symmetry of the leading-in arrangements. In order to become satisfied that it was possible to fulfil this condition, the two aerials in the earlier experiments were first erected at right angles to the transmitting station, in which position their horizontal portions would be ineffective. Hence the two aerial currents should be equal and it should be found that $\theta = 45°$. By means of this check it was proved that the desired equality of the two aerials could be established to a sufficient degree of approximation for the experiments to be successful.

Another very necessary precaution which had to be taken was to ensure that there was no "direct pick up" by any part of the receiving system except the aerials. It was therefore found necessary thoroughly to screen the amplifier and its associated circuits, even including the telephone leads.

Taking the above precautions, a number of different sized aerials were tested by the method, and the value of D obtained in each case. These values are recorded in the table below for three different sizes of aerials on various wave-lengths between 365 and 7 000 metres.

TABLE SHOWING DIRECTIVITY OF VARIOUS AERIALS AS DETERMINED EXPERIMENTALLY.

Metres.	Size of Aerial.			D
	Length (l)	Height (h)	$\frac{l}{h}$	$= \frac{\text{current diff.}}{\text{current average}}$
7 000	200 ft.	10 ft.	20	0.24
2 500	,,	,,	,,	0.30
750	,,	,,	,,	0.60
750	100 ft.	,,	10	0.36
365	80 ft.	20 ft.	4	0.23

On the longer wave-lengths very long low aerials were employed, as will be seen from the table. This was necessary in order to obtain large enough directive effects to be measured. Even with the ratio of length to height as large as twenty, the directive effect on a 7 000 metre wave is quite small—the difference in current between the worst and best positions of the aerial being only 24 per cent. For the same aerial on 750 metres the difference, however, is as high as 60 per cent.

On the shortest wave-lengths such long aerials could not be used with this method, as their natural wave-length became of the same order as that of the waves, thus making the balancing of the aerials too difficult a task. For such waves, therefore, a smaller value of l/h had to be employed. Thus it was not possible on a given aerial to obtain a value of D for all wave-lengths.

The directivity of the "four to one" aerial on 365 metres is of particular interest, since it is a typical broadcasting aerial of standard 100 feet length, measured for a wave-length in the middle of the present British broadcasting band. Its directional properties are seen to be comparatively small, but hardly small enough to be completely ignored where it is a question of obtaining the utmost from a given aerial.

III.—Discussion of the above Results.

These experimental results, besides being in themselves of value as giving definite information with regard to certain aerials on certain wave-lengths, can fortunately be used to obtain more general information, if we now return to the theoretical considerations which were laid aside earlier.

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We can now insert the experimentally obtained value of D in Equation (1), and thus obtain a value for the ratio K_l/K_h, since this is the only unknown factor now remaining in this equation. If we do this, we find that for every experimental observation recorded in the table, the value of K_l/K_h lies between 0.44 and 0.64 ($tan\ \beta$ being obtained on the assumption $\sigma = 10^8$ E.S.U. from Equation (3)).

Suppose then we take $K_l\ K_h = 0.5$ as the approximate value of this ratio for all aerials and wave-lengths within the limits of the experiments, we shall then be able to calculate D for any desired case. The approximation is admittedly a rough one—the maximum possible error cannot be safely put at less than 30 per cent.—but the majority of the values will be much closer to truth than this; whereas, even assuming the maximum error, the information obtained will be sufficiently accurate for most purposes and will give a considerably better idea of the directive properties of aerials than exists at present.

Thus, taking $K_l/K_h = 0.5$, we get from Equation (2) the simple relation—

$$D = l/h\ tan\ \beta \quad .. \quad .. \quad (5)$$

In Fig. 5 the values of D obtained from Equation (5) are shown plotted against the ratio l/h for a number of different wave-lengths. The graphs are, of course, straight lines passing through the origin; their slope becoming steeper and steeper as the wave-length decreases.

Outside the limits of wave-lengths 365 to 7 000 metres and below the value $l/h = 4$, we are extrapolating in assuming $K_l/K_h = 0.5$; the values must, therefore, be accepted in these regions with reserve. The graphs are accordingly here distinguished from the more certain cases by employing dotted lines. From the simplest considerations, however, there does not seem much reason for supposing that this constant should differ greatly from the assumed value in the particular cases covered by the graphs; except, possibly, where l/h is very small. Since D is then also obviously negligibly small, however, the case is not worth considering.

The results obtained from these curves cannot be applied to cases where l becomes comparable with the wave-length, for in such cases the phase differences in the wave at different parts along the aerial become of importance and may greatly enhance the directive effect, as in the Beverage or wave antenna.

If we then take these graphs as valid approximations we have all the information we require on the question of aerial directivity. Consider first of all the wave-lengths 400 and 300 metres, which are of particular interest since they may be considered as representing the broadcasting band. We see at once that unless the aerial is exceptionally long compared to its height, say $l/h = 10$—a very unlikely value with the present legal limitation of the aerial to 100 feet—its directional properties are small, D being less than half. On the most typical kind of broadcasting aerial (*e.g.*, $l/h = 2$ or 3) the directivity does not exceed 0.16, so that allowing for all possible errors we are safe in asserting that for such an aerial the difference in current between its worst and best

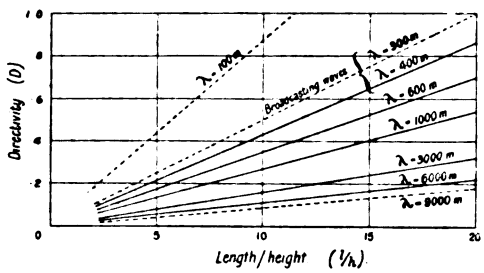

Fig. 5.

positions is less than 20 per cent.—Such a difference, it is true, may be worth while taking into account in the same way that other minor points are attended to in the construction of an efficient set, but it is definitely of secondary importance.

When we come to consider a standard 100-foot aerial being used for waves of length greater than 1 000 metres, say, on the broadcasting wave of 1 700 metres of the high power station, the directive effect is only about 5 per cent., and in such cases it may be neglected altogether in comparison with other considerations.

Some idea of the weight which should be attached to the directional properties of an aerial can be got from the fact shown by simple calculation, that if the erection of a broadcasting aerial in its least favourable direction is unavoidable, the adverse effect can be more than compensated for under the worst conditions by increasing the height

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of the aerial by three feet; while, again, if we take a vertical aerial and bend over the top of it into the most favourable direction the advantage gained by the directional effect is outweighed by the disadvantage due to the decrease in the vertical height.

IV.—Conclusions.

The investigation described has verified the possession by inverted "L" aerials of directional characteristics and shown that in accordance with Zenneck's theory the directional effect is greater for short waves than for long, and increases with the ratio length/height of the aerial.

From the results of the direct measurements of the directivity of various aerials and from an application of Zenneck's theory to the problem we conclude that, within the present commercial range of wave-lengths and with normal aerials the directive effect is of secondary importance only, becoming entirely negligible on long waves received on short aerials, but of just sufficient importance on broadcasting waves (300-600 metres) to be taken into account with the other secondary factors.

It must, however, be borne in mind that these conclusions are only valid for aerials erected in localities where the conductivity of the earth is approximately the same as that assumed in the calculations.

There is strong evidence that this value is but little departed from by all normal localities in England, but for places where the ground is very dry—too dry, say, for any vegetation—it is probable that the conductivity may have a much lower value, giving rise to enhanced directional effects.

In such places the directivity could, however, be easily determined from the formula given above, when once the conductivity had been determined.

On sea, on the other hand, where the conductivity is some hundred times greater than that assumed above, the directional effects will be about 1/10 of their land value, and consequently entirely negligible.

Precision Measuring Instruments. [R384·009

THE importance of accurate measurement in all research work is so great that it is gratifying to note that instrument makers are turning their attention to the design of precision instruments particularly adapted to the needs of the wireless experimenter. We have recently had the opportunity of testing three well-designed instruments that form part of a series now being put on the market by Messrs. F. C. Heaybeard & Co., 8-9, Talbot Court, E.C.3, and in planning the calibration it is evident that the object aimed at was to provide a maximum number of the most generally useful ranges and to make both volts and ammeters capable of universal application so far as D.C. work is concerned.

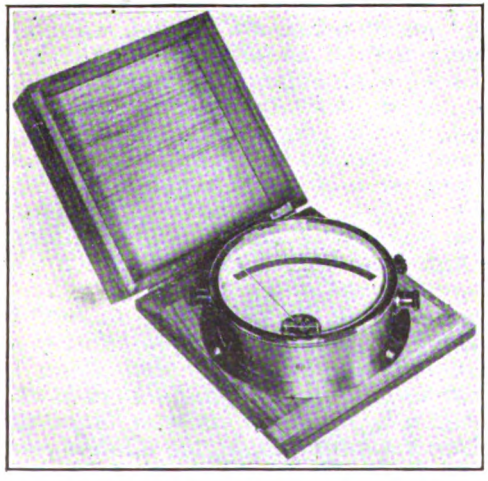

Fig. 1. *The Universal Testing Meter.*

Fig. 4 illustrates a very convenient form of combined portable moving coil, milliamp-voltammeter, contained in a well-made wooden box of suitable size for the pocket. When the lid is slid off and reversed the box, as will be seen in the photograph, forms a robust support for the instrument. Although the scale is only 2¼ ins. in diameter, the divisions are clear and open and the fine point of the diamond-shaped end of the pointer enables a fraction of a division to be read with ease and accuracy. The voltmeter ranges are 0—6 and 0—120 and are therefore exactly suited to the testing of either L.T. or H.T. batteries and, since the resistance of the 120-volt range is 40 000 ohms, it can be used for testing the latter without fear of damage to the battery—a rather important matter that is too frequently overlooked by designers of pocket instruments. Equal forethought has been shown in the milliamp and ampere ranges. The shunt box, seen below the instrument, is constructed of highly finished brass and the four terminals enable the following useful ranges to be obtained: 0—3, 0—12, 0—120 milliamps and 0—6 amps. This renders the instrument available for any current measurement from the plate current of a single valve up to the charging current of a reasonably large accumulator. The price of the instrument alone is 37s. 6d. The shunt box costs 17s. 6d. and the wooden case 10s. 6d.

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Fig. 1 illustrates an instrument that justifies the maker's description of it as a "Radio Universal Testing Meter." It is mounted in a finely finished

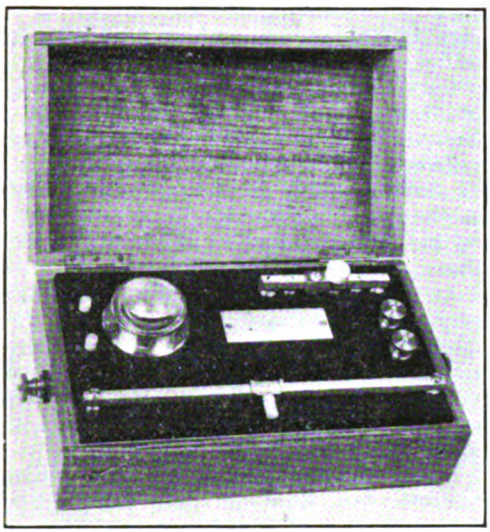

Fig. 2. *The Wheatstone Bridge.*

brass case which is set on a base-board that also forms the lid of a stout carrying case. An ingenious form of hinge permits the lid to be detached instantly from the case. The scale is 6 ins. in diameter and an anti-parallax mirror is fitted which, in conjunction with a knife-edge pointer, makes it an easy matter to read to .2 of a division. The following table gives the ranges of the instrument and the respective resistances :—

Volt Ranges.	Milliamp Ranges.	Resistance.
0— 5	0— .5	800 ohms.
0—100	0— 10	123 ,,
Resistance.	0— 100	12.72 ,,
500 ohms.	0—1 000	1.287 ,,
10 000 ,,		

In addition, 5 and 10 ampere shunts can be supplied and also external series resistances giving a top scale reading up to 3 000 volts.

The damping of the instrument is so proportioned that it is very "comfortable" to use, being nicely dead-beat, but at the same time so free that the observer need have no fear of pivot friction. A further refinement is also supplied in the form of a magnetic calibration shunt. The price of the instrument, complete in case, is £6 6s. and the external shunts for the 5 and 10 amp ranges 15s. each. Prices of the high voltage series resistances can be obtained on specifying the desired range.

A very convenient form of Wheatstone Bridge is illustrated in Fig. 2 and Fig. 3 shows the internal connections. This compact instrument combines the facility of operation associated with the metre bridge with the requirements of the P.O. type and, as its dimensions are only 9½ by 5½ by 3½ inches, it is more portable than either.

Fig. 4 shows that the spiral P.Q. takes the place of the long slide wire in the one case and the plug in resistance arm in the other. The various ratios, the values of which are clearly shown, are

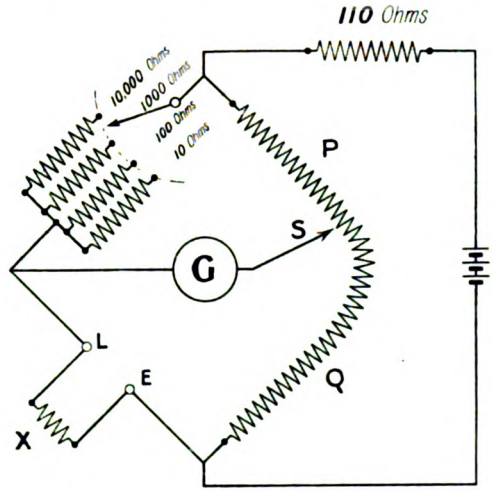

Fig. 3. *Schematic Diagram of the Bridge.*

introduced as desired by a switch of special design. The moving-coil instrument is built into the panel and is fitted with a powerful magnifying lens with the zero point in its exact focus. To the left of this, in the photograph, can be seen the two press buttons for the battery and galvanometer circuits. Readings are made, after balance has been obtained, on a silvered scale which carries a slider (*S*) fitted with a fine pointer. Measurements ranging from .1 ohm to 1 megohm can be made easily and swiftly on the instrument, which is priced at £7 7s. Larger instruments, covering other ranges up to 200 megohms, can be supplied at proportionately increased prices, and another pattern has a range of .01 to 20 megohms. Price £9 12s. 6d. The instrument described, however, provides a very useful bridge for all ordinary purposes at a very modest price. The finish is excellent in every way: accuracy about in 1 1000.

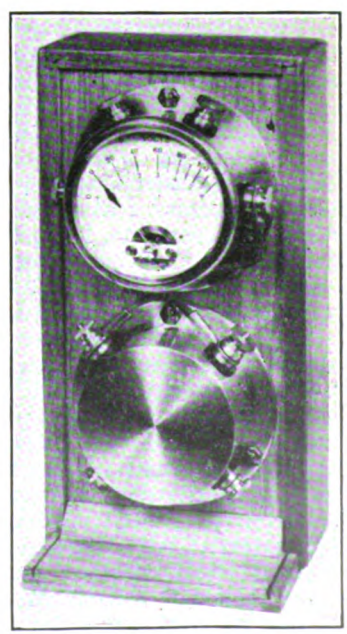

Fig. 4. *The Portable Testing Set.*

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Long-Distance Work.

By Hugh N. Ryan (5BV). **[R545·009·2.**

RATHER less work than usual has been done this month. This is partly due to rather unfavourable weather conditions and partly to the Paris Convention taking many of us from our stations for a week.

However, a number of the Paris delegates have done their best to make up for lost time, and many other stations have kept the work going, so there is some interesting work to report.

The 20-metre work, which I mentioned last month, has been proceeding regularly, though nothing of any great interest has occurred in its continuance so far as transatlantic work is concerned. A very great step in our work has, however, been achieved on this wave-length in working with Australia. The contact established can hardly be termed "daylight communication" in the same sense as our daylight working with America, but it was accomplished when it was daylight at both ends, which is as near to daylight working as we can get when dealing with the Antipodes. The question of "which way round?" arises again, but as far as our present knowledge goes, the answer is probably "the daylight way."

Australian 20-metre signals were first heard in this country by 2KF and 6UV, and communication was first established by 2OD. The Australian station was 2CM. The most important feature of the 2OD—2CM communication was, I think, not the fact of contact being established (as we all knew it soon would be), but the fact that the work was done to a pre-arranged schedule.

Famous amateur pioneer achievements in the past have usually been of a somewhat "fluky" nature in the first case, and though always followed up by work which has established their usefulness, their apparent "flukiness" has been the subject of some adverse criticism on amateur achievement. 2OD has supplied the final answer to all such criticism, by making the first daylight contact across the world "to schedule." F.B., O.M.!

Another event, which promised to be of great interest, was 5LF's Atlantic voyage for the purpose of experimenting on the short waves. He was to spend about a week crossing to the United States, a week in the States, and a week returning, carrying on the boat transmitters and receivers for 20, 40 and 90 metres. The object was, of course, to work American and European amateurs during the voyages, and obtain records of the variation of his and our signal strengths at different points. At the time of writing the outward voyage is over, but the return voyage not yet commenced. He will be back in England by the time this article appears.

The results obtained on the outward journey were, from our end, disappointing, although he probably has some interesting records of our signals. His own signals were often heard, and of good strength, but rendered extremely difficult to read by violent swinging. This is a matter of great surprise, as the signals from 5LF's home station are notable for their steadiness. However, he has been informed of the trouble, and will probably have remedied it for the return voyage, when we hope to have some interesting tests with him. His call sign on the boat is 6YM, and he will welcome reports from all who have heard his signals from the boat, which reports should be sent to 5LF's home address.

The month has brought, as we feared, a considerable crop of atmospherics, but we have had quite a number of clear nights. American signals on 90 metres are disappearing rather more rapidly than I anticipated, and two-way work on this wave has now almost ceased, although the Americans may still be heard fairly often.

Two-way work across the Atlantic is, however, going strong on 45 metres now that many of us have our 23 and 45-metre licences. I doubt if even 45 metres will cross the "Pond" right through the summer, but it is certainly giving better results than 90 metres; 20 metres is still somewhat difficult to handle for prolonged communication, and has not yet taken its place in this work, although much fruitful experimenting is going on, as already reported.

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Some months ago I commented upon the paucity of our work with Canada, as compared with that with America. I discussed this at Paris with Major Borrett (C1DD), and he said that this fact is noticed and greatly deplored in Canada. He ascribes it to the fact that we do not listen sufficiently on the 125-metre wave, on which so many Canadians call us. They are extremely keen on working with us, as one would expect, and are very disappointed at their calls to us, on 125 metres, and their replies to our tests, eliciting no response other than further calls from us to the Americans. The remedy is clearly indicated, and is in our hands.

Now that Newfoundland is "on the air," it is hoped in the near future to run an "all British" relay right round the world, going through Canada, Newfoundland, Australia and New Zealand and back through South Africa. The Canadians are the moving spirits in this effort, and it is up to us to back it up.

8AR is the first transmitting amateur in Newfoundland, and hopes soon to be QSO Great Britain, as does 1AC, a similarly-placed amateur in Brazil. We had the pleasure of meeting both of them in Paris, and vowed to "get QSO" next autumn.

After the Convention, Brazil 1AC, accompanied by Swedish SMYY, travelled across the Pyrenees into Spain, taking a small portable transmitter, with which they were able to work G2FU from Andorra, in the Pyrenees.

In London very little work has been done. 2KF has not been on very much, and 5LF is away, though before his departure he worked America regularly on 23 and 45 metres. 6NF has nearly ceased working, being in need of a rest after a strenuous winter. 2OD's work has already been mentioned. 6QB has been exploring the forgotten region of 200 metres, and reports that things still happen there, while QRM is not what it used to be. Which reminds me that an American has worked a New Zealander on 200 metres. Well, many of us are licensed for 440 metres, and quite a few have not forgotten our old 1 000 metre licences! Perhaps our flight down the scale may one day reverse its direction.

6QB intends running a small generator by weights hung out of the window, and wound up at intervals, so he says. 6UV is regularly on 45 and 23 metres and having great success on both waves. He and 2KF receive A2CM well on 20 metres, but have not, at the time of writing, established contact.

2AYL, a fairly recent Chatham station, has received many Americans on a single valve Flewelling, without any aerial or earth, chiefly on the lower waves. 5QV has worked Florida, and received confirmed signals from 7ADQ (Seattle). 2TO has just obtained a licence for very high power on short waves, and will soon be using it.

5IG, of Havant, is licensed for a particularly large assortment of waves between 15 and 200 metres, but works mostly on 87 and 95, on which he has worked all over Europe. He would welcome reports of his signals on any wave-length.

6RY, of Bath, has practically given up 90-metre DX, and devotes himself almost entirely to 20 metres, where he transmits and receives with great success. 2GY, of Bristol, is working all over Europe, and should soon reach farther.

5SI, of Shrewsbury, is apparently bent on breaking all the world's low-power records. In February he worked America with 2.2 watts; in March, Finland with .8 watt; in April, Sweden with .36 watt.

6JV (Norwich) has accomplished similar, but not quite so startling, low-power results on the 40-metre band. 2AWP, of Yorkshire, has now a full licence with his call changed to 6YR, and would appreciate reports.

2GZ, an old friend of the pre-broadcasting days, is now in operation again after two years' inactivity, and his signals have reached America already. 2KK has been working chiefly on the receiving side, and has received signals from a large number of countries.

Mr. Gordon Ritchie, of Glasgow, has also been doing some interesting reception work, which confirms entirely the figures for distribution of 20-metre signals which I gave last month, except that in one instance he heard two Americans, evidently about 200 miles apart, working together. This interesting case is the first exception to my last month's figures that I have yet met. Apparently the 25-400 mile "shadow" is not quite inevitable.

Next month's report will probably deal almost entirely with 23 and 45-metre work. Please let me have reports by 10th June, mentioning especially the extent to which 90-metre work is still practicable.

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For the Esperantists. [R800

La Internacia Amatora Radio-Konferenco.

Originala Raporto de nia Speciala Korespondanto.

La unua Internacia Konferenco de Radio-Amatoroj okazis en Parizo de la 14a ĝis 18a Aprilo, sub la prezido de S-ro. Edouard Belin, Prezidanto de la Radio-Klubo de Francujo kaj Honora Prezidanto de la Internacia Radio-Asocio. La kunvenoj okazis en la Fakultato de Sciencoj.

Subtenante S-ron. Belin dum la solena malferma ceremonio je mardo, estis la Generalo Ferrié, Estro de la Telegrafa Fako de la Franca Armeo, kaj S-ro. Hiram P. Maxim, Prezidanto de la Amerika Radio-Relaja Ligo.

La ĉefa celo de la kongreso estis la fondo de Internacia Unio de Radio-Amatoroj, kiu unuigos la radio-amatorojn en ĉiu parto de la mondo. Inter la gravaj temoj diskutotaj estis la alĝustigo de ondolongoj inter amatoroj, la organizo de transatlantikaj provoj, la rearanĝo de voksignaloj, kaj fine, la elekto de internacia helpa lingvo.

Dum la unua kunveno, la ĉambrego estis plenplena, kun pli ol 250 delegitoj kaj kongresanoj el dudek-du landoj. La Prezidanto bonvenis la delegitojn franclingve; ankaŭ faris mallongajn paroladojn Gen. Ferrié, S-ro. Maxim, kaj aliaj naciaj reprezentantoj.

Poste oni longe diskutis la tagordon de la kongreso. Ĉiun regulon oni diskutis kaj voĉdonis aparte. Oni uzis du lingvojn, la franca kaj la angla. Kiam ajn delegito parolis angle, lia parolado estis tradukita francen, kaj kontraŭe. S-ro. Leon Deloy, la fama franca amatoro, estis la ĉef-interpretisto, kaj li estis helpita de angla delegito; dum unu okazo tri oficialaj interpretistoj samtempe deĵoris.

Estis mem-evidente, eĉ je la komenco, ke lingva malfacilo kaŭzus multe da ĝeno, kvankam oni uzis nur du lingvojn. Oni malŝparis multege da tempo pro la ofta tradukado kaj pro la deziro havigi ĝustajn tradukojn de paroladoj faritaj en unu aŭ alia de la du lingvoj. Kelkafoje, la originalaj reguloj en franca lingvo ne estis klare komprenitaj eĉ de la francoj mem, kaj pro tio, kompreneble, estis neeble fari ĝustan tradukon. Kiel ekzemplon, mi povas citi la regulon kiu, laŭ la franca originalo, pritraktis la "kvorumon" necesan por efektivigi la voĉdonojn de kunvenoj. Dum pli ol duon-horo oni argumentadis pri la supozita signifo de tiu regulo, sen sukceso, kaj eĉ dum la sama vespero, kiam okazis akcepto ĉe la Hotelo Lutetia, kelkaj personoj kunvenis neformale (inter ili S-roj. Belin, Maxim, Warner, Corret, Mesny, Turner kaj Epton) por trovi la ĝustan signifon de la regulo. Oni fine interkonsentis, post konsulto kun la aŭtoro de la originalo, ke anstataŭ la vorto "kvorumo" oni devus uzi la vorton "plimulto"!

Dum la posttagmezo, por rapidigi la laborojn, oni decidis elekti komisionon por ĉiu temo; ĉiu komisiono kunvenu aparte kaj samtempe por diskuti detalojn kaj poste prezenti raporton al la plena kunsido. Ĉiu nacio tenis kunvenon de siaj reprezentantoj, kaj selektis membron por ĉiu komisiono pri kiu ĝi interesis sin. Tia membro havos la rajton voĉdoni por sia lando en tiu komisiono, por kiu oni lin selektis. Oni ankaŭ konsentis, ke ĉiu lando havos nur unu voĉdonon en ĉiu komisiono.

Kiam komisiono finos sian laboron, ĝi prezentos raporton al la plena kunsido, kaj oni permesos diskutadon de la aliaj kongresanoj. Se la raporto renkontos ĝeneralan aprobon, oni permesos voĉdonon, sed nur tiuj landoj, kiuj havas reprezentantojn sur la komisiono koncernita, rajtus voĉdoni ĉe la plena kunsido. Jen unika metodo por voĉdono, sed ĝi funkciis tre bone.

Dum la dua tago, merkredo, oni faris malmulton ĉe la plena kunsido. Oni finis diskutadon pri la tagordo, korektis kelkajn erarojn faritajn hieraŭ. Poste la diversaj komisionoj kunvenis.

Ĉi-sube estas presita raporto pri la kunsidoj de la Komisiono pri Internacia Lingvo.

Je la tria tago, ĵaŭdo, la Komisiono pri Ondolongoj prezentis sian raporton. Ĝi rekomendis, ke amatoraj stacioj uzu ondolongojn inter 115 kaj 95 metroj, inter

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75 kaj 70 metroj, kaj inter 47 kaj 43 metroj, sed kvankam la Kongreso aprobis la raporton, estis komprenite, ke tiuj rekomendoj estas nur dezirespriminoj kaj ke sole la registaroj rajtas decidi pri ili.

Poste, la diversaj komisionoj daŭrigis siajn diskutojn, kaj ĉiu, kun escepto de la Komisiono pri la proponita Unio, finis sian laboron la saman posttagmezon. La tasko de la Komisiono pri la Unio estis tiel peza, ke ĝi devis ree kunveni dum la noktomezo por konsideri la multajn regulojn de la konstitucio. Unu el la membroj de tiu komisiono estis tiel laborema, ke dum 24 horoj li ne manĝis, sed la venontan matenon oni donacis al li longegan francan panon, ĉirkaŭ kiuestis volvita belega silka rubando!

Ce la plena kunsido dum la kvara tago, vendredo, la Komisionoj pri Transatlantikaj Provoj kaj Voksignaloj prezentis siajn raportojn. La rekomendoj, ke por ĉiuj provoj oni ĉiam uzu la Tempon de Greenwich, kaj pri normigo de ĉiuj mallongigoj pri forteco de signaloj, stato de vetero, k.t.p., estis unuanime aprobitaj.

Ĉe la sama kunsido la Komisiono pri fondo de la proponita Unio prezentis sian raporton, kaj post iom da diskutado, oniĝin unuanime aprobis inter granda entuziasmo. Tiel naskiĝis la INTERNACIA AMATORA RADIO-UNIO, kiu markas la komencon de nova epoko en la historio de amatora radio.

Kelkaj el la pli gravaj punktoj pri la aprobita konstitucio eble interesos niajn legantojn.

La originala intenco de la Amerika Ligo estis, ke la Unio konsistu el naciaj radiosocietoj, kiuj plejparte interesas sin pri du-voja telegrafa interkomunikado, sed post kontraŭstaro de aliaj landoj, oni decidis, ke la Unio konsistu el individuoj. Kvankam la ĉefa celo de la Unio estos antaŭenigi la interkomunikadon telegrafan, ĉiu persono, kiu montras seriozan intereson pri la progreso de la radio-arto, rajtos membriĝi. Tiel, ne nur telegrafemuloj, sed ankaŭ eksperimentistoj povos aliĝi.

La ĉiujara kotizaĵo estos unu dolaro, kaj kiam en iu lando estos almenaŭ 25 membroj, oni povos fondi nacian sekcion, kiu rajtos al unu voĉdono pri aferoj de la Unio. Oni tenos kongreson ĉiudujare, kaj la oficistoj dejoros du jarojn.

Por la komenco, la sidejo de la oficejo de la Unio estos en Usono, kaj preskaŭ ĉiuj oficistoj estos usonanoj, kaj la oficiala organo de la Amerika Ligo, nome "Q.S.T.," estos la oficiala organo de la Unio. Tamen, tio estos nur provizora.

Sabato estis la lasta tago de la Kongreso; la ferma kunsido okazis dum la posttagmezo.

La raporto de la Komisiono pri Internacia Lingvo estis prezentita ĉe ĉi tiu kunveno, kaj post iom da diskuto la tri rekomendoj de la komisiono estis aprobitaj. Mallonge, la Kongreso decidis adopti Esperanton kiel sian oficialan lingvon kaj rekomendi ĝian studadon kaj uzadon inter radio-amatoroj. Plena raporto sekvas ĉisube.

Oni esprimis multan ĝojon pri la rezultoj atingitaj ĉe la kongreso, kaj oni esprimis tutkoran dankon al diversaj oficistoj, kiuj organizis la kongreson.

Raporto de la Komisiono pri INTERNACIA HELPA LINGVO.

Landoj, kies reprezentantoj ĉeestis:—

Granda Britujo, Germanujo, Argentino, Aŭstrio, Kanado, Usono, Francujo, Hungarujo, Italujo, Irlando, Japanujo, Nederlando, Polujo, Svedujo, Svislando, Ĉeĥo-Slovakujo, Novlando, Urugvajo, kaj Hispanujo.

UNUA KUNSIDO.

La unua kunsido okazis je merkredo, 15a Aprilo. Oni elektis la jenajn oficistojn de la komisiono:

Prezidanto: D-ro. E. Privat (Svislando);

Vic-Prezidantoj: S-roj. P. K. Turner (Britujo) kaj Nordin (Svedujo);

Sekretario: S-ro. Epton (Irlando).

Dek-unu delegitoj ĉeestis la kunvenon.

Post mallonga diskutado pri tagordo, oni unuanime decidis dividi la laboron en du partojn: telefonio kaj telegrafio. Oni do malfermis la diskutadon rilate al la telefona flanko.

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Troviĝis antaŭ la komisiono kvar definitivaj proponoj pri lingvo elektota: angla, Esperanto, Ido kaj Interlingua. Oni unue diskutadis, ĉu oni preferu nacian lingvon, ekz., angla, aŭ artefaritan lingvon. Krom unu sindeteno, oni unuanime decidis favori artefaritan lingvon.

La Sveda delegito tiam proponis, ke la elekto de artefarita lingvo estu lasata al komitato de spertuloj, kiu povus konsideri la aferon kaj raporti al la plej proksima kongreso post du jaroj. Kelkaj membroj kontraŭstaris tiun proponon, konstatantaj ĝian gravecon kaj urĝecon. Ili ankaŭ opiniis, ke eĉ post du jaroj, la spertula komitato plej certe ne povus decidiĝi pri plej taŭga lingvo. Per 13 voĉdonoj por, neniu kontraŭ, kaj unu sindeteno, la komisiono malakceptis la proponon pri prokrasto.

La komisiono tiam ekzamenis la pretendojn de Interlingua, Ido kaj Esperanto. Kelkaj personoj parolis angle aŭ france, aliaj esperante aŭ ide. La Prezidanto tradukis ĉiun paroladon rapide kaj ĝuste en la francan kaj anglan lingvojn.

Post longa debato, la komisiono decidis, per 13 voĉdonoj kontraŭ 1, kaj unu sindeteno, rekomendi al la Kongreso la adopton de ESPERANTO pro ĝia granda disvastiĝo, kaj pro tio, ke ĝi estas lingvo jam uzata praktike. Jen teksto de la rezolucio akceptita :—

"La Unua Internacia Kongreso de Radio-Amatoroj, bone scianta la malfacilaĵojn kaŭzitajn ce internacia interrilato pro la diverseco de lingvoj, rekomendas la studon kaj uzon de Esperanto kiel la helpa lingvo de radio-telefona komunikado kaj sendado, kaj de resumoj aŭ tradukoj en gazetoj kaj kongresoj."

Pro tio, ke la horo malfruiĝis, la komisiono decidis denove kunsidi la venontan tagon por diskuti proponon de D-ro. Corret (Francujo), ke oni aldonu rekomendon rilate al radio-telegrafio en okazoj kiam la korespondantoj havas neniun lingvon komunan.

Oni elektis kiel raportontojn al la Plena Kunsido, D-rojn. Corret kaj Privat.

DUA KUNSIDO.

La komisiono kunvenis posttagmeze, je ĵaŭdo, 16a Aprilo.

Krom la landoj reprezentitaj je la unua kunsido, la jenaj pluaj landoj sendis delegitojn al la dua kunsido: Argentino, Germanujo, Japanujo, kaj Hispanujo.

La delegitoj el Polujo kaj Hungarujo forestis. La Franca delegito reprezentis ankaŭ Ĉeĥo-Slovakujon kaj Italujon.

Sciigite pri la rezulto de la unua kunsido, la argentina, japana kaj germana delegitoj subtenis la rekomendon jam faritan.

La komisiono tiam diskutis la proponon de D-ro. Corret rilate al radio-telegrafio. Post longa debato, per 12 voĉdonoj kontraŭ 2, kaj unu sindeteno, oni akceptis la jenan aldonan rekomendon :—

"La sama rekomendo rilatas al radio-telegrafaj komunikoj kiam la korespondantoj ne povas komprenigi sin per iu nacia lingvo."

Sro. Turner (Granda Britujo) tiam proponis, ke la Kongreso tuj efektivigu la decidon (se akceptota) per adopto de Esperanto kiel sia propra helpa lingvo, flanke de la naciaj lingvoj uzitaj, kaj per publikigo de la rezultoj de siaj diskutadoj en tiu lingvo.

Post mallonga diskuto, oni decidis, per 8 voĉdonoj kontraŭ 5, kun unu sindeteno, aldoni la jenan rekomendon al la du antaŭaj rezolucioj :—

"Sekve de tiu ĉi decido, la Kongreso adoptas Esperanton kiel sian propran helpan lingvon flanke de la naciaj lingvoj uzataj."

La tasko de la komisiono tiam finiĝis, kaj la delegitoj el Svedujo, Francujo, Granda Britujo, kaj Urugvajo, proponis koran dankesprimon al la Prezidanto pro lia pacienco kaj senpartieco dum la diskutado. Oni entuziasme aplaŭdis tiun dankesprimon.

Dankante la komisionon, la Prezidanto anoncis, ke la sindetenoj de Svislando (kies reprezentanto li estas) estis pro tio, ke li devis resti neŭtrala kiel prezidanto de la komisiono.

La kunsido tiam fermiĝis.

PLENA KONGRESA KUNSIDO

Ĉe la lasta kunsido de la Kongreso, je sabato, la 18a de Aprilo, D-ro. Privat legis la raporton de la Komisiono pri Internacia Lingvo en franca kaj angla lingvoj.

La Prezidanto de la Kongreso, S-ro. Belin, tiam malfermis la temon por diskutado. S-ro. Nordin (Svedujo) ripetis angle paroladon, kiun li antaŭe faris ĉe kunsido de la komisiono, en kiu li kritikis Espernaton kaj fanfaronis la virtojn de Ido, kaj li denove proponis, ke oni sendu la demandon al komitato de spertuloj.

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Respondis D-ro. Corret (Francujo), kiu citis eltiraĵojn el la decido lastjara de la Amerika Radio-Relaja Ligo, kiu tiam decidis subteni Esperanton. Li multe amuzis la aŭskultantojn per cito de ĉirkaŭ dudek artefaritaj lingvoj, kiuj pretendas, ke ili estas plibonaj ol Esperanto aŭ Ido.

Alia Sveda delegito tiam parolis favore de la angla lingvo kiel la internacia lingvo. kaj konstatis, ke en lia lando preskaŭ ĉiu amatoro konas anglan, kaj ili tial rejetis Esperanton *kaj Idon.* Tiu deklaro nuligis la efikon de la parolado de la alia sveda delegito.

S-ro. Warner (Usono) diris ke, pro la deklaro de la A.R.R.L., ili intencis voĉdoni por la unuaj du rezolucioj, kun la rezervo, jam anoncita, ke se iam en la estonteco iu gravega internacia aŭtoritata komisiono, kies kompetenteco estos akceptita, decidos favore de iu alia lingvo aŭ de ia modifo de Esperanto, ili estus liberaj sekvi ĝian rekomendon.

S-ro. Isbrucker (Nederlando), kiu parolis esperante, konstatis, ke la aŭtoro de Esperanto mem antaŭ multaj jaroj, deklaris sin preta akcepti la decidon de iu aŭtoritata komisiono, simila al tiu aludita de S-ro. Warner. Lian paroladon tradukis en anglan kaj francan D-ro Privat.

Post paroladoj de S-ro. Ryan (Britujo), kiu favoris anglan, kaj S-ro. Grenkamp (Polujo) pro Esperanto, kaj de S-ro. Usami (Japanujo), kiu faris bonegan paroladon en Esperanto, konstatanta ke, en sia lando, la eŭropaj lingvoj, kiel ekzemple la angla, estas tre malfacilaj, dum Esperanto estas tre populara pro sia simpleco, la Prezidanto fermis la diskutadon kaj petis voĉdonon pri la rekomendoj de la komisiono.

La unua rekomendo rilate al telefonio estis aprobita per 12 voĉdonoj kontraŭ 2: la dua per 14 kontraŭ 2: kaj la tria per 12 kontraŭ 5.

La Prezidanto tiam anoncis, ke ĉiuj rekomendoj de la komisiono estis akceptitaj, kaj la rezulto estis multe aplaŭdita.

Diversajoj.

Dum la mateno de merkredo, granda partio, veturanta en benkĉaroj, vojaĝis al Malmaison, la laborejo de S-ro. Belin, la Prezidanto de la Kongreso. S-ro. Belin mem kondukis la vizitatojn tra sian laborejon, klarigante detalojn pri sia mirinda aparato por telegrafado fadene aŭ senfadene de veraj mesaĝoj aŭ bildoj. Oni vidis multajn fotografaĵojn senditajn per la aparato.

S-ro. Epton, Sekretario de la *Internacia Radio, Asocio* (kies Prezidanto estas S-ro. Belin), parolis mallonge en Esperanto, dankante S-ron. Belin pro lia malavaro, kaj en la nomo de la Esperantistoj, kiuj ĉeestas, deziris al li sukceson. La parolado, verŝajne komprenebla al ĉiu ĉeestanto, estis multe aplaŭdita.

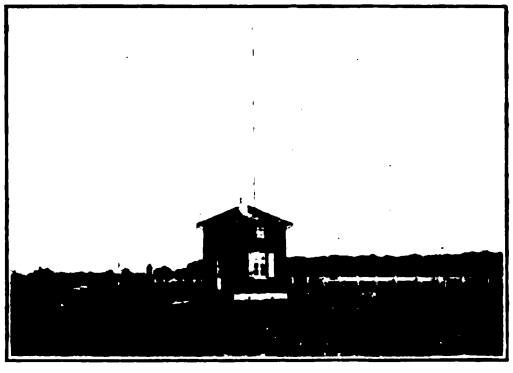
Dum sama vespero, ĉe la fama *Trocadero,* oni aranĝis senpagan kinematografan programon, montrante filmon nomitan "La Mistera Voĉo de la Ondoj." Ankaŭ faris franclingve paroladon D-ro. Pierre Corret, pri Radio. Granda amaso ĉeestis.

Je jaŭdo matene, oni faris oficialan viziton al la senda stacio ĉe Eiffel'a Turo. La ĉef-inĝeniero kondukis la partion tra la diversajn cambrojn.

Tre frue vendredon matene, kelkaj kongresanoj vojaĝis aŭtomobile al la fama senda stacio ĉe Sainte-Assise, la plej granda stacio en la mondo.

La lasta okazintaĵo de la Kongreso estis festeno ĉe la Hotel Lutetia, kaj preskaŭ ĉiu kongresano ĉeestis.

Tiel finiĝis semajno, kiu certe estos gravega en la historio de amatora radio, kaj ni esperas, ke la lingvaj malfacilaĵoj tiel rimarkeblaj ĉe la kongreso, estos forigitaj per la saĝa decido adopti kiel helpan lingvon, la lingvon Esperanto!



As a sequel to the involuntary flight of the R 33, the above photograph is interesting. It shows the receiving aerial of the wireless station at Basle, one of the latest aerodromes to be equipped with receiving and transmitting apparatus. The transmitting aerial is shown on a later page.

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Letters of interest to experimenters are always welcome. In publishing such communications the Editors do not necessarily endorse any technical or general statements which they may contain.

Corrugated Diaphragms.

The Editor, E.W. & W.E.

SIR, — In the April No., Vol. II., No. 19, page 454, particulars appear regarding the use of corrugated diaphragms. It would be interesting to know if priority or Master Patent rights are claimed for this particular form of construction.

It is curious that there is not a single loud-speaker on the market employing this system of diaphragms (I am open to correction).

Personally I think it is the only correct method, for the original Edison, and also the Edison Bell phonographs, used this on their reproducers fifteen years ago, and no other form of phonograph or gramophone music has equalled that obtained when the diaphragm has been made of thin corrugated copper.

There is an opening here for some brainy person.

J. P. J. CHAPMAN.

Glen Lee,
Alumdale Road,
Westbourne, Bournemouth.

[We believe, as a matter of fact, the well-known Western Electric loud-speaker uses a corrugated diaphragm of fibre.—Ed., E.W. & W.E.].

Parasitic Losses in Coils.

The Editor, E.W. & W.E.

SIR,—In the article by Mr. R. M. Wilmotte in your current issue, statements which appear to be incorrect are made regarding parasitic losses. On p. 477, column 2, the assertion is made that "at all frequencies and for all sizes of objects, the loss will be greater the lower the specific resistance of the material." For high frequencies, however, the opposite is the truth. As Mr. Wilmotte shows, the loss is proportional to

$$\frac{R\omega^2}{R^2+L^2\omega^2}$$

Now it is only at low frequencies that the square of the reactance ($L^2\omega^2$) is small compared with R^2. At radio frequencies, the value of the current (for such conductors as copper, brass, aluminium, etc.) is practically determined by the reactance only and is the same with either metal, other conditions remaining constant. The loss therefore increases with the specific resistance of the metal.

As an example, consider a small closed ring of wire an inch or two in diameter. If we calculate the square of its reactance at half a million cycles per sec. (600 metres) we find that it is several hundred times the resistance. The current induced in such a ring when placed in a magnetic field will therefore be the same whether the ring be of copper or brass. The power dissipated in the ring however will be greater for the brass.

A simple experiment shows that the induced current is independent of the resistance. A coil of a dozen turns was wound on a 4 in. former. It was tuned by a condenser and loosely coupled to a heterodyne wavemeter. Three similar discs of copper, brass and aluminium 3½ in. diameter and of equal thicknesses were prepared. The inductance of the coil was measured (1) alone, (2) with each of the discs placed inside the coil at the centre. The effect of each disc was to reduce the coil inductance to 47 per cent. of its full value, but there was no measurable difference between the effects of the three materials, the figures agreeing to one-half per cent. This shows that the currents in the three discs were closely equal.

The case is similar to that of the commercial current transformer in which the secondary current is, over a wide range, independent of the resistance of the secondary circuit. The secondary winding is purposely made with high inductance to ensure this result.

R. C. CLINKER.

Engineering Laboratory,
The British Thomson-Houston Co., Ltd.,
Rugby.

The Editor, E.W. & W.E.

SIR,—With reference to Mr. R. C. Clinker's letter pointing out an apparent error in my article in the May issue, I wish to point out that the metallic objects I had in mind were small, very much smaller than 1 in., such as the usual size of screws that are used in coils for receiving sets.

With this limitation, which I certainly ought to have inserted, and which I thank Mr. Clinker for pointing out, I think my statement is correct.

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For large objects, and for very high frequencies, my statement does not hold, but Mr. Clinker's argument is far from conclusive, nor do his experiments prove that the distribution of current is the same for the three discs used. I fear that in a letter I cannot deal with this fully, but I can state that for large objects at high frequencies, the loss due to eddy currents is proportional to the square root of the specific resistance of the material. This is not difficult to prove, but I shall not take up your space unless some of your readers are particularly interested.

RAYMOND M. WILMOTTE.

4, Priory Mansions,
Drayton Gardens,
S.W.10.

Wire Gauges.

The Editor, E.W. & W.E.

SIR,—Most amateur transmitters who really make their own components probably base their work on Ballantine's *Radio Telephony for Amateurs*, there being no equivalent published in England, and they probably find that they are unable to get their windings in the space given. This is not necessarily because of bad workmanship, but because they are using S.W.G. wire while copper wire in the U.S.A. is measured by Browne & Sharpe's gauge, which in some cases is much smaller.

A. WM. BOWMAN.

83, Lister Street,
Rotherham.

Following is a list of Brown & Sharpe wire gauges, together with the corresponding diameter in inches, and the nearest British Standard gauge.

B. & S.	Diameter in inches.	S.W.G.
8	.128 5	10
10	.101 9	12
12	.080 8	14
16	.050 8	18
20	.032 1	21
24	.020 1	25
28	.012 6	30
32	.008 0	35
36	.005 0	40
40	.003 1	44

Celluloid as an Insulator.

The Editor, E.W. & W.E.

SIR,—With reference to Mr. Simeon's article on "The Aerial-Earth System," p. 507, second column, I notice that he suggests the use of celluloid for insulation in low loss coils.

Apparently he has not yet tried this or he would not be so anxious to recommend it to others. The dielectric losses in celluloid are very much higher than those in wax, and more than compensate for the gain in reduction of capacity.

D. DINKLER.

13, Lockharton Crescent,
Edinburgh.

Fine Wire Coils.

The Editor, E.W. & W.E.

SIR,—In your April issue, Mr. Reeves points out that he experienced an increase in amplification of the higher side bands of telephony by using fine wire coils (probably resistance wire) and pushing reaction almost to the point of oscillation. An explanation of this may be found in the fact that the resonance curve of a tightly coupled circuit has two humps, these humps approaching one another as coupling is decreased, the spreading of the humps being governed by the resistance of the coils.

Now it will be apparent from the above facts that if we are receiving a modulated wave, and tune in between these two humps, all the high harmonics of the modulation will come under the influence of the humps, which spread out more and more as the *reaction* is increased. Increase of reaction necessitates the increase of coupling of the plate and grid coils, or the windings of the H.F. transformer.

In reducing coupling the two humps meet when $2\pi fm = \sqrt{R_1' R_2'}$, R_1' and R_2' being the resistance of primary and secondary windings, and M the mutual inductance.

The effect may be far more pronounced in long wave reception, as the necessary coils increase in resistance.

S. WILSON BROWNING.

43, Clarnda Park, East,
Kingstown, Co. Dublin.

More Short Wave Work.

The Editor, E.W. & W.E.

SIR,—Further to my letter to you dated 31st March, I have pleasure in informing you that on Monday, 6th April, at 04.00 GMT, R CB8 and myself were successful in establishing two-way working.

Communication was carried on easily for nearly one hour and we signed off voluntarily, it being daylight here. My wave-length was 95 metres while CB8 worked on 63 metres. His signals are very QSA here, and he reports mine as "QSA and steady."

As I am now in touch with R CB8 it will not be necessary for me to carry out the schedule given in mine of 31st March, and I shall now be working as follows for the whole of May and June :—

Wednesdays :	04.00 to 05.00
Thursdays :	20.45 to 21.30
Saturdays :	17.15 to 17.45—(calling Z 4AG)
Saturdays :	20.00 to 21.00

All times are GMT and the wave-length 95 metres.

J. S. STREETER
(O A4Z).

Myrtle Grove,
Irwell Street, Observatory,
Cape Town.

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Call Signs.

The Editor, E.W. & W.E.

SIR,—I should esteem it a favour if you would publish in your next issue the address of amateur station 5IS (power 10 watts, 150/200 metres, C.W. and telephony) as below.

All DX reports welcomed and cards answered.

Thanking you in anticipation, and with congratulations on your excellent journal.

P. JOHNSON.

49, Carson Road,
Dulwich, London, S.E.21.

The Editor, E.W. & W.E.

SIR,—Will you please note that the call sign 2ZB, previously owned by an amateur at Clacton-on-Sea, has been re-allotted to me. Reports on reception of my signals will be welcomed.

L. F. ALDOUS (2ZB).

St. Hilda,
48, Harpenden Road,
West Norwood, S.E.27.

The Editor, E.W. & W.E.

SIR,—The call sign 2SW which formerly belonged to the Marconi Wireless Telegraph Co., Ltd., Strand, London, has now been allocated to me; and as I believe that reports are still being addressed to London, I should be very much obliged if you will give the correct address in a future issue of your paper.

A. H. FIELDING.

Pomona,
32, Stanley Avenue,
Birkdale, Lancashire.

The Editor, E.W. & W.E.

SIR,—Reports have reached me twice within the current month that 5QK, the call sign of this Society, has been received at Sutton, Surrey, strength R5, wave-length 93 metres. Our transmitter has been temporarily dismantled and is not in use.

I should therefore much appreciate any evidence which would help me in locating the offender who is using our call, and should feel much obliged if you could insert a notice to this effect in your next issue of E.W. & W.E. My informant states that there is no room for doubt that the call used is G5QK, otherwise I would not worry you with the matter.

FRED WALLER,
Hon. Sec., Southend & Dis. Radio Society.

Eastwood House,
Rochford, Essex.

The Editor, E.W. & W.E.

SIR,—I should be very much obliged if you would draw attention to the following: The name and address of 6HC (Six Harry Charlie) are: H. Cooper, "Morning Dawn," Burnt Ash Lane, Bromley, Kent.

Apparently my address is unknown to many amateurs, and I understand that several have reports for me, but do not know where to send them.

H. COOPER.

Bromley.

The Editor, E.W. & W.E.

SIR,—Would you mind making it known that 2OZ (two oh zed) has been held by me for some time, and not by the owner of the name and address shown in most lists? I understand several have tried to establish contact, and have probably been unable to write, or have written to the address in the directories.

JOHN W. NORTON.

"Konrad," Salisbury Road,
Exmouth, Devon.

The Editor, E.W. & W.E.

SIR,—Station 2QB, located at this address, is now active on 190 metres. Any reports on transmissions will be welcomed and all cards answered.

R. W. BAILEY.

Broadeaves,
Fairfield Road,
Widnes, Lancs.

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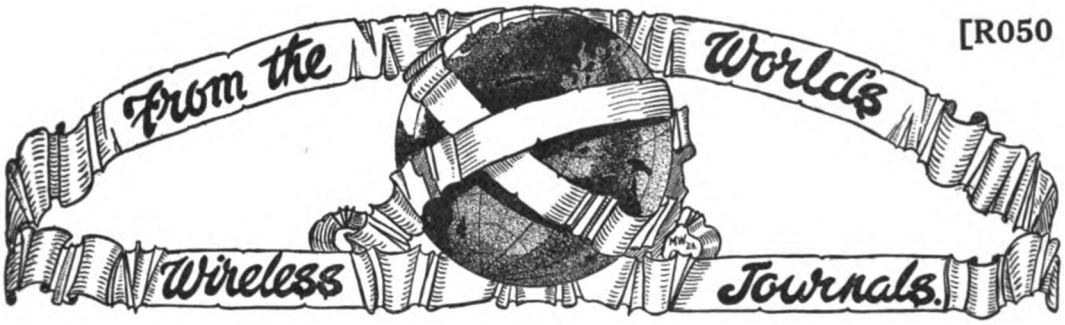

[R050

R100.—GENERAL PRINCIPLES AND THEORY.

R149.—THE RECTIFYING DETECTOR.—F. M. Colebrook, B.Sc. (*Exp. W.*, May, 1925).

The third and concluding portion of a paper dealing exhaustively with the problem of rectification with special reference to wireless detectors.

R200.—MEASUREMENTS AND STANDARDS.

R201.060.—THE TESTING AND MEASUREMENT OF WIRELESS COMPONENTS.—P. K. Turner (*Exp. W.*, May, 1925).

A paper read before the Radio Society of Great Britain on 25th March, 1925. The measurement of valve characteristics, high-frequency resistance, losses in inductance coils, power factor of circuits, measurement of capacity, calibration of condensers, and determination of the characteristics of crystal detectors are described.

R213.—IMPROVED CATHODE-RAY TUBE METHOD FOR THE HARMONIC COMPARISON OF FREQUENCIES.—D. W. Dye, B.Sc. (Proc. Phys. Soc. Lond., April, 1925).

A method is described in which a circular or elliptical time base is provided, the oscillations under investigation being made to produce a radial displacement. The circular time-trace is obtained by splitting the output of an audio-frequency oscillator into two components differing in phase by ninety degrees and applying these two components to the two pairs of control plates in a cathode-ray oscillograph. By making the time-trace an elongated ellipse instead of a circle a considerable portion of the displacements under observation may be observed against a nearly linear time base. By means of the method the wave-forms of the currents and voltages in the grid and anode circuits of valve oscillators may be investigated for harmonics.

R213.—A METHOD OF MEASURING RADIO FREQUENCY BY MEANS OF A HARMONIC GENERATOR.—A. Hund (*Proc. I.R.E.*, April, 1925).

An improved method has been developed for standardising a wavemeter by means of the harmonics produced by a simple type of harmonic generator the fundamental frequency of which is an audio-frequency alternating current. The fundamental may be checked against a standard frequency tuning fork and the harmonics may be utilised up to the 100th and higher. Very sharp settings are rendered possible by the use of a visual resonance indicator.

R240.—AN ELECTROMETER METHOD FOR THE MEASUREMENT OF RADIO-FREQUENCY RESISTANCE.—P. O. Pedersen (*Proc. I.R.E.*, April, 1925).

The author criticises the existing methods for the measurement of radio-frequency resistance and describes a new electrometer method, where a quadrant electrometer is put across the inductance of an oscillatory circuit. The condenser of this circuit is charged to the voltage V_0 and discharged through the inductance by means of a special key. The throw of the electrometer will then be proportional to $V_0^2 - \frac{L}{2R}$. The theory of the method is given and it is shown how to eliminate the different possible sources of error. With this method the radio-frequency resistance of even a very feebly damped circuit may be determined with an error well within one part in a thousand, and this determination may be made in a few seconds.

R270.—SOME TRANS-PACIFIC RADIO FIELD INTENSITY MEASUREMENTS.—L. W. Austin (*Proc. I.R.E.*, April, 1925).

Description of measurements on the daylight radio field intensity produced in San Diego, California, by the arc stations at Cavite, Philippine Islands, 11,800 km., and Malabar, Java, 14,700 km. distant. This distance is nearly twice as great as any previously studied except for a few scattered measurements. The average observed intensities were, from Cavite 2.04 microvolts per metre, and from Malabar 4.02 microvolts per metre, while those calculated from the Austin-Cohen formula are respectively 0.69 and 1.83 microvolts per metre. These ratios of observed to calculated values indicate an increase in the divergence from the formula with increasing distance, but not so great as was indicated by earlier scattered observations.

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R300.—APPARATUS AND EQUIPMENT.

R329.—Top-Loading Antennas and Loops.—W. H. Murphy (*Q.S.T.*, May, 1925).

Some experiments were made by the writer to ascertain whether there is any advantage in inserting loading inductances high up in the aerial system between the down-lead and the horizontal top portion. The conclusion reached is that top-loading might have distinct advantages under certain conditions such as in cases where height and span are limited.

R336.—The Magnetron Amplifier and Power Oscillator.—Frank R. Elder (*Proc. I.R.E.*, April, 1925).

The magnetron is essentially a two-electrode thermionic discharge tube in which the electron current is controlled by an electromagnetic field and not by an electrostatic control grid. The paper opens with a discussion of details of tube design together with a partial list of the sizes studied. A *résumé* of the general theory of magnetic control is given. The first part of the paper deals with the magnetron as an amplifier on 8 000 metres. The circuit is described and the results of tests on tube impedance, design of control coils, and the variation of amplification with anode voltage, design of polarising field coils, and description of a four-stage amplifier are given.

The second part is concerned with the use of the magnetron as a generator. The circuit and necessary apparatus are described in considerable detail. The conditions necessary for efficient operation are then discussed. Based on observed wave shapes of anode voltage and anode current, formulæ for suitable circuit design are developed, and the complete calculation of a typical circuit is given. The results of tests at various voltages are then compared with calculated performance and representative oscillograms shown. In conclusion a few factors which may cause departure from theoretical results are briefly discussed.

R337.—Quelques Applications Scientifiques des Lampes à 3 et 4 Electrodes Associées à des Cellules Photoélectriques.—Général Ferrié.

A description of some methods of employing the potassium photoelectric cell to record optical phenomena. The potassium cell consists essentially of a vacuum tube containing an anode and a potassium cathode. When light falls on the potassium the latter emits electrons and a space-current may be established if a suitable potential is applied. The chief difficulty is the minute magnitude of this space-current; it rarely exceeds a microampere under the most intense illumination. A number of methods are given of employing three- and four-electrode valves to magnify the effect of the photoelectric currents so that they may actuate some recording instrument.

R337.—A Study of the Production of "Flashing" in Air Electric Discharge Tubes.—J. Taylor, B.Sc. and J. Clarkson, B.Sc. (*Proc. Phys. Soc., Lond.*, April, 1925).

This paper deals with an extension of the study of flashing in discharge tubes containing air instead of neon and helium. Only very slow periods of flashing, of the order of a second, are dealt with.

R340.—Novel Current Supply System for Audions.—C. V. Logwood (*Proc. I.R.E.*, April, 1925.

A number of substitutes doing away with H.T. and L.T. batteries for receiving sets are discussed. Amongst the devices which have been tried with varying degrees of success are rectified and filtered alternating current supplies, thermo-electric devices, radio-frequency current generators, electrolytic rectifiers, and motor generators. The author makes some interesting suggestions about the construction of thermo-couple generators for supplying filament current and describes one which he constructed to operate off a bunsen burner and deliver 1 ampere at 8 volts.

R342.6.—Improving the R.F. Amplifier.—E. E. Burns (*Q.S.T.*, May, 1925).

A method is described of overcoming the effect of grid-plate capacity in high-frequency amplifiers by making this capacity one arm of an all-condenser Wheatstone Bridge.

R342.7.—Testing for Distortion.—A. P. Castellain, B.Sc. (*W. World*, 6th May, 1925).

Some experiments carried out with the aid of a simple home-made oscillograph to investigate the distortion in an audio-frequency amplifier working with different conditions of grid bias, loading, etc.

R376.—Note on Telephone Receiver Impedance.—E. Z. Stowell (*Proc. I.R.E.*, April, 1925).

Measurements were made on about 50 pairs of telephones, representing 14 makes. It was found in most cases that the resonant frequency lies between 9 000 and 15 000 cycles per second and that the resistance at this frequency is of the order of 100 000 to 200 000 ohms. At frequencies above 50,000 the telephones may be considered as a condenser of .000 1 mf.

R376.3.—Loud Speaker Horns.—Dr. J. P. Minton (*W. Age*, May, 1925).

The characteristics of sound radiation and reflection in different sizes and shapes are discussed. A number of experimentally-determined curves are given which show the relation between the dimensions of a conical horn and the response at different frequencies. Horn resonance, as distinct from diaphragm resonance, depends upon reflection at the open end and by suitable design this resonance at one particular frequency may be eliminated. In order to obtain a maximum intensity of sound from a conical horn of given length its solid angle has a certain optimum value; the longer the horn the smaller is the magnitude of this optimum solid angle. Horns are investigated whose variations of diameter with length conform to the following mathematical functions: Exponential, logarithmic, parabolic, hypocycloid, hyperbolic, cissoid, cubic and cone.

R382.1.—Parasitic Losses in Inductance Coils at Radio Frequencies.—R. M. Wilmotte, B.A. (*Exp. W.*, May, 1925).

The most important sources of loss in inductance coils are discussed. The losses due to eddy currents in neighbouring metallic objects are first dealt with. The concluding part of the article deals with dielectric losses and some practical data are given on the effect on coil resistance of the insulating material used for the wire and its state of dryness.

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R385.52.—LE MICROPHONE À RUBAN.—M. Henrard (*Onde Elec.*, March, 1925).

A description of the Siemens-Halske microphone. This belongs to the magnetophone order. A corrugated band of aluminium alloy is suspended by its ends between the poles of a powerful magnet. Impinging sound waves cause the band to vibrate; this causes the flux cut by the band to vary and therefore potentials are set up across the ends of the bands. In principle this microphone is really the converse of the Einthoven string galvanometer.

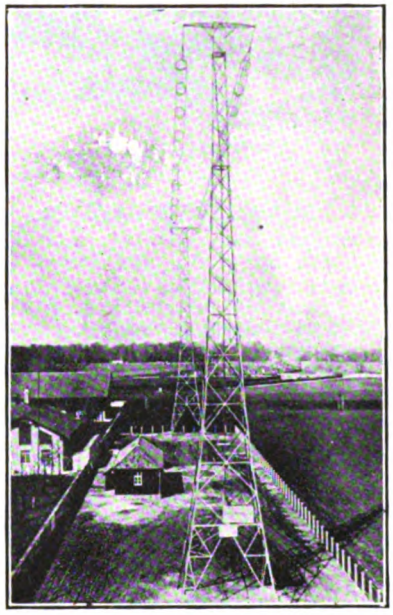
R400.—SYSTEMS OF WORKING.

R401.24.—PIONEER SHORT-WAVE WORK.—F. C. Jones (6XM) (*Q.S.T.*, May, 1925).

Some experimental work on wave-lengths between 1 and 20 metres is described, special attention being devoted to the wave-length of 3 metres. For the latter wave-length a parabolic reflector was used at the transmitter, the receiver being portable and used in conjunction with a single-wire aerial operating on a harmonic. A number of polar radiation curves were plotted, and are reproduced, showing the effect of varying the number and length of wires in the reflector. With a reflector consisting of only three wires the gain in received power was about 10/1 compared with a single transmitting aerial without reflector. The transmitter valve circuits were coupled to the aerial at the focus of the reflector by means of a radio transmission line. Signals on 3 metres were received up to a distance of 14 miles on quite low power. The screening effect of hills was found to be very pronounced. With a 50-watt set working on 13 metres a distance of 1 500 miles was covered easily. The various circuits used are given and the question of wavemeters is dealt with briefly.

R423.0124.—A TRANSMITTING CIRCUIT FOR SHORT WAVE-LENGTHS.—E. H. Robinson (*Exp. W.*, May, 1925).

A novel method of tuning an aerial below its fundamental for short-wave transmission.



The Transmitting Station and Aerial at Basle Aerodrome (*see page* 587).

Although levity is not usually a feature of our pages, the following amused us sufficiently to make us believe that it would also be appreciated by our readers.

Neutrodyne's Melody in CW. [R084

This was the yell of a B.C.L.
In the land of the U.S. afar:
" The code I'll cram like a regular ham
Till I master the dah-du-dah."
And he built him a set, with which to get
The hams with their dash and dot;
He chuckled with glee as he tuned in a " 3,"
But this was all he got.

A " 7 " came thru with a long CQ,
Which tickled our friend to death.
All limp and slack, he settled back
For a chance to catch his breath.
" Aha ! " said the ham, " he's raised his man.
To copy this bird is pie;
His fist is great, he's raised an " 8,"
But this was the 8's reply :—

(*Chorus.*)
O.K., O.M., O.K. U.R.,
F.B. ES. Q.S.A.
Ill tri mi fone—pse QRK
Pse QRK mi fone.

" H—— ! " quoth he, " that's no good to me;
I was taught to talk by mother.
So with an expert twist of his nimble wrist,
He then tuned in another.
With a high-pitched whine, a powerful " 9 "
Was pounding " CQ " for fair.
But this was the trash that was tearing a gash
In the poor, inoffensive air.
(*Chorus—as before.*)

His heart was strong and he strung along
Till he covered the country o'er.
He sure was game, but when morning came,
He was feeling mighty sore.
For the love of Mike, are they all alike
From Atlantic to 'Frisco Bay?
From Bangor, Maine to the Andes chain,
I've heard a thousand say :—
(*Chorus—as before.*)

K. S.

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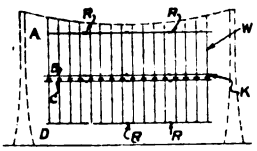
(The following notes are based on information supplied by Mr. Eric Potter, Patent Agent, Lonsdale Chambers, 27, Chancery Lane, W.C.2.)

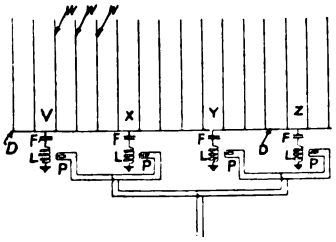
[R008

SHORT WAVE AERIALS.

(Application dates, June 21st, 1923 and September 6th, 1923. No. 226,246.)

A very interesting short wave aerial is described in British Patent No. 226,246 by C. S. Franklin. The form of the aerial is shown in the upper half of the illustration, while the manner in which it is energised is shown in the bottom portion. The aerial is constructed of a number of vertical wires or rods W, which are spaced a fraction of a wave-length apart in a plane which is at right angles to the desired direction of working. The wires or rods are connected together at the top and bottom, and each rod, together with the wires connecting it to the top and bottom of the next rod, is in tune with the waves to be used when in its position in the aerial. An aerial system of this nature can be extended indefinitely, and by making the system several times as long as the length of the wave to be employed, very sharp transmission or reception in a horizontal plane is obtained, the directional effect being a function of the length in relation to the wave-length. Thus, in the accompanying illustration, the vertical wires or rods *W* are fixed between the horizontal rods *A*, *B*, *C*, and *D*. The two systems *AB* and *CD* are coupled together electrostatically through condensers *K*. Oscillations produced in any one of these systems will cause corresponding oscillations to be produced in the system above or below it. The lengths of the vertical members and the coupling capacities should be so adjusted that the currents are in the same phase in each system. It is essential that no oscillations in a horizontal direction occur in the aerial system, as this would represent a source of considerable loss, and accordingly it is found desirable to include resistances *R* in the horizontal members, *A*, *B*, *C* and *D*, which tend to suppress any oscillations. The lower portion of the illustration indicates one method of feeding the system. *D* represents the bottom horizontal wire of the aerial system, and four equi-distant points *V X Y Z* are chosen along this. These are connected through condensers *F* and inductances *L* (which constitute the secondaries of a transformer), either to earth or a balancing capacity. The primaries *P* of the transformer are connected by separate cables of equal length. It is necessary for efficient working that no reflection of the oscillations transmitted through the cable by the generator should take place at the feeding points. This can be accomplished by making the ratio of the transformer such that the effective resistance of each portion of the aerial fed by the transformer as applied to the cable is equal to the critical resistance required at the cable terminals to prevent reflection. Under these conditions no stationary surface will be produced. A convenient form of cable consists of parallel tubes or rods arranged in a Lecher wire system, which are enclosed in metal conduits for screening purposes.





CONSTANT RECEPTION.

(Convention date (United States), 28th December, 1922. No. 209,037.)

A rather interesting system of reception is described in British Patent No. 209,037 by Marconi's Wireless Telegraph Company, Limited and R. H. Ranger. Many schemes have been devised for eliminating interference effects caused by atmospheric disturbances. Some of the most successful have consisted in receiving the given signal at two or more points, and conveying the received currents to a central station where they are combined. A modification of this system is described in the above patent, and consists essentially in providing two receiving systems, one of which is normally inoperative, and is only rendered operative by the signal being received in the other system. It is somewhat difficult to describe the exact functioning of the system in so limited a space, but the reader should be able to grasp the idea by reference to the accompanying illustration. Thus *X* and *Y* represent two receiving systems. The aerial circuits are connected to two detectors *A* and *A*1. The detectors are followed by two amplifiers *B* and *B*1. The amplifier *B*1 is coupled to another three-electrode valve *C*, the output of which is connected through land lines to the central station. The amplifier *B*, however, is coupled to a two-electrode

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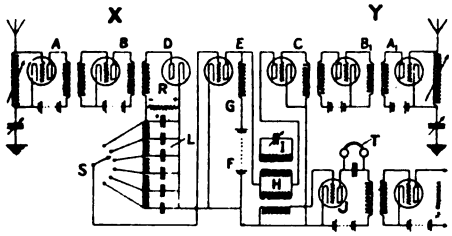
valve *D*. Connected in the anode circuit of the two-electrode valve *D* there is a resistance *R*, across which there is an artificial line *L*, consisting of the usual capacity and inductance network provided with a selector switch *S* for adjusting it. The positive terminal of the resistance *R* is connected to the filament of a three-electrode valve *E*. The grid of this valve is connected to the selector switch *S*. The anodes of the valves *E* and *C* are connected together as shown, and derive their potential from a battery *F*, through a large inductance *G*, which has considerable resistance. The output circuit of the valve *C* contains a coupling coil *H*, the primary of which is in shunt with a coupled trap circuit *I*. The secondary of the coupler *H* is connected to the input of a valve *J* which contains the telephone receivers *T*, the latter also being coupled to a further amplifier operating a commercial recorder. Let us consider the effect

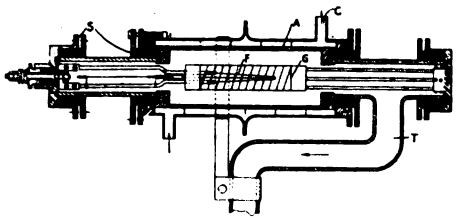


of receiving a signal on the system *X*. The amplified signal will eventually be impressed upon the plate-filament circuit of the two-electrode valve *D*. As the current through the rectifier only flows in one direction, one end of the resistance will always be positive with respect to the other. As soon as the voltage is impressed upon the plate the current will vary and one end of the resistance will become more negative. To this resistance is connected the grid of the valve *E*, which will accordingly be given a negative bias. The valve *E* is normally operated so that when there is no negative bias on the grid it draws a large current from the battery *F*. When a signal is received upon the system *X*, the bias on the grid will give it sufficient potential practically to stop the flow of the current. Let us now consider the effect of simultaneously receiving the signal on the system *Y*. Oscillations will eventually be impressed upon the grid circuit of the valve *C*. Since the battery *F* supplies the anodes of both these valves it will be seen that when no bias is on the grid of the valve *E* approximately twice the current which flows when the grid is biased as described will flow through the battery *F* and the inductance *G*. It is stated that 220 volts have been used for the battery *F*, a drop of 40 volts being obtained across the inductance *G*. The valve *E* is operated at such a point that with an anode potential of 180 volts (220-40) the impressed voltage on the grid is insufficient to control the output. This is the condition which obtains when no signal is received from the system *X*. However, when a signal is received from *X*, the grid of the valve *E* will receive a negative bias sufficient to stop the anode current, and will therefore decrease the current through the battery *F* to approximately half its value. The voltage drop through the inductance *G* will then decrease from about 40 to 20 volts, which accordingly raises the potential of the anode of the valve *C* to approximately 200 volts. Under these conditions the valve *C* will be operative, and the received signal will be amplified and passed on to the telephone receivers *T*. Thus it will be seen that the telephones or other indicating device are only rendered operative so long as signals are received simultaneously on both systems. Most of the interference caused by static is due to local discharges, and it is not so likely that similar static discharges will be received simultaneously by both systems. According to this arrangement therefore, it will be obvious that the interference from static is considerably minimised, and it appears to us to be a very sound scheme.

THE HOLWECK DEMOUNTABLE VALVE.

(*Convention date* (*France*), *27th October*, 1922. *No.* 206,155.)

The construction of the Holweck demountable valve is described by F. Holweck in British Patent No. 206,155, and is illustrated by the accompanying diagram. The construction will not be dealt with in great detail, as those desirous of studying the valve to such an extent can find all the information in the specification; only a brief outline of the general construction will therefore be given. Briefly the invention consists in making a thermionic valve which can be taken to pieces and put together again. The container of the valve consists of a metal anode *A* which is provided with a cooling chamber *C*. Inside the valve are mounted the usual grid and filament *G* and *F* respectively. The filament leads are brought out at one end, while the grid lead is brought out at the other end. In order to maintain an air-tight joint two stuffing boxes *S* are provided at each end of the tube through which the filament leads pass. The other end of the container of the valve is connected to a member *T* of the shape shown, which is also secured in position by stuffing boxes. This tubular member *T* is connected to the well-known Holweck molecular pump. The valve is of considerable interest owing to the fact that it is really pumped each



time it is in use. Should the filament fail, for example, the filament support member has merely to be unscrewed, removed, the new filament fixed and reinserted, the valve then being exhausted once more.

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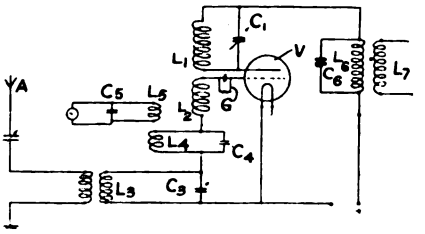
HETERODYNE RECEPTION.

(*Application date, 11th August, 1923. No. 225,907.*)

A SYSTEM of heterodyne reception is described by T. H. Kinman in British Patent No. 225,907. The accompanying illustration shows one form of the invention, and one great advantage of the method lies in the fact that radiation from the aerial due to the local oscillation is practically non-existent. The idea consists essentially in providing two sources of



local oscillation which beat together, this beat frequency being combined with the frequency of the incoming signals. The resultant beat can be at an audible or inaudible frequency, and can be further amplified or rectified as desired. Thus, in the accompanying illustration, the valve *V* produces continuous oscillations by virtue of the coupling between *L1 C1* and *L2*. The incoming signals are received by an aerial *A* and are transferred to a tuned circuit *L3 C3*, which is included in the grid circuit of the valve *V*. A third tuned circuit *L4 C4* is also included in the grid circuit, and this is coupled to a tuned circuit *L5 C5*, which is associated with another source of local oscillations. The anode circuit of the valve also includes the circuit *L6 C6*, which is tuned to the resultant beat note. Thus, the oscillations produced in the circuit *L5 C5* beat with those produced by the valve *V*, and combine with the incoming oscillations, which are also introduced into the grid circuit, and are rectified by the valve by virtue of the grid-leak and condenser *G*. In the particular circuit shown the resultant beat note is intended to be further amplified, and the circuit *L6 C6* is therefore coupled to another inductance *L7*. We imagine that this system of reception should prove of value to experimenters working on the lower wavelengths, which are very crowded.

HIGH FREQUENCY CORES.

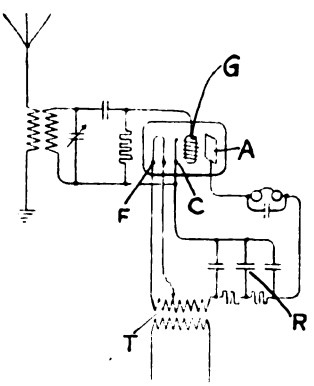
(*Convention date (Germany), 25th July, 1923. No. 219,703.*)

The Telefunken Gesellschaft fur Drahtlose Telegraphie M.B.H. describe in British Patent No. 219,703 an interesting method of constructing an iron core for use in high frequency circuits. Essentially the invention consists in making a core of colloidal metal, which is preferably enclosed in a porcelain tube of some description. When a closed core is required some form of tubular vessel closed upon itself is used. The colloidal metal may be obtained in any suitable manner, formation by an electrical arc under water being mentioned. A claim is made for the use of ferro-magnetic metal in colloidal form for a core for use in high frequency circuits. We should imagine that this would be quite efficient.

A REAL A.C. VALVE.

(*Convention date (United States), 3rd October, 1922. No. 205,058.*)

Many readers will no doubt remember hearing of a special type of alternating current valve which was described by Hull a year or two ago. Details of the valve and the circuit are disclosed in British Patent No. 205,058, which is granted to The British Thomson-Houston Company, Limited and A. W. Hull. The object of the invention is to provide a valve which derives its electrical emission from an electrode which is heated by an alternating current, but at the same time rectifies a fairly high voltage alternating current for the purpose of obtaining its anode supply. One form of circuit is shown in the upper half of the illustration, while a diagrammatic representation of the valve itself is shown in the lower portion. The valve contains a filament *F* which is heated by alternating current. Surrounding this filament there is a metallic cylinder *C* which is coated externally with some compound which has a good emission at low temperature. Around this cylinder there is a grid *G*, and surrounding the grid there is the usual anode *A*. The operation of the device is exceedingly ingenious. Considering first of all the filament *F* and the inside of the cylinder *C*, this, it will be seen, is comparable with an ordinary two-electrode rectifier valve. Referring to the circuit it will be seen that a transformer *T* is connected between the filament and the cylinder *C* through a filter *R*. The filament, it will be noticed, is also heated from this transformer, a tapping being taken to provide a suitable voltage. Here, then, we have an ordinary two-electrode valve, the filament, of course, becoming positive with respect to the cylinder. Owing to the heat from the filament the cylinder becomes sufficiently hot to emit electrons from its external surface. Hence the cylinder can be regarded as an ordinary equi-potential cathode, and the other electrodes cause the device to operate as an ordinary three-electrode valve, which obtains its anode supply from the current which is rectified between the filament and the cathode. The circuit shown, of course, is an ordinary single valve non-regenerative detector, working with grid condenser rectification. We should imagine that this scheme is one of the most satisfactory solutions of the problem of using alternating current with receiver valves.



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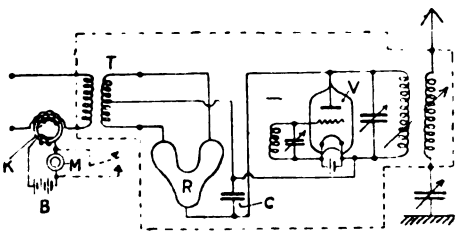
A SYSTEM OF MODULATION.

(*Convention date* (*Germany*), *16th September*, 1922. *No.* 204,064.)

(*Application date* (*United Kingdom*), *17th September*, 1923.)

A system of modulation is described by Dr. E. F. Huth and Dr. L. Kuhn in British Patent No. 204,064. This is rather novel, in that the actual modulation is carried out in the supply to the anode, before being rectified. One method of carrying the invention into effect is shown in the accompanying illustration. A valve *V* is used as the generator of high frequency current, a tuned grid oscillator being shown coupled to a condenser *C*. It will be noticed that the anode supply is obtained from a step-up transformer *T*, which is connected to a rectifier *R*, consisting of a double anode two-electrode valve. The transformer is supplied with alternating current of a fairly high frequency, the frequency after rectification, of course, being doubled. If an alternator working at a frequency of a few thousand cycles

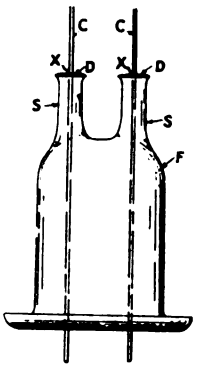


be connected to the transformer, and if the modulating means be inserted in the primary winding of this transformer, then assuming that rectification takes place according to a linear function, the voltage of the rectified current will at any particular instant be proportional to the primary current, and consequently proportional to the modulating current. Owing to the high frequency of the supply current the condenser across the rectified output can be exceedingly small. If this condenser were made too large many of the speech frequencies would be lost, as its impedance would be substantially zero. It will be seen that by using a fairly high frequency supply current it is possible to include the modulating means directly in the circuit. Thus, referring again to the illustration, we find that the microphone *M*, which is energised by a battery *B*, is connected with the primary circuit of the transformer *T* by means of a closed core modulation transformer *K*.

AN INTERESTING VALVE SEAL.

(*Convention date* (*United States*) *2nd May*, 1923. *No.* 215,317.)

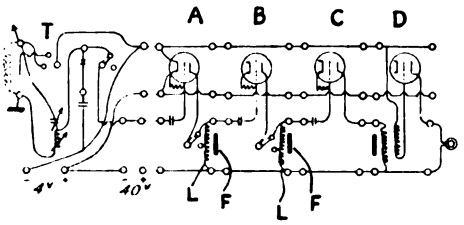
A rather interesting valve seal is described in British Patent No. 215,317 by the Western Electric Company Limited and V. L. Ronci. The object of the invention is to provide an effective gas-tight seal for a leading-in conductor capable of carrying a fairly heavy current. This object is attained by means of a metal disc sealed into a glass tube, through the centre of which the leading-in conductor passes, to which it is fixed by solder. The wire and disc are joined together by a solder containing no volatilisable material. A solder suitable for this purpose is an alloy containing the metal of which the leading-in wire and the disc are composed. An interesting point is that the proportions of the constituents are such that the addition to the alloy of more of the metal of which the disc and the leading-in wire are composed increases the melting point. This ensures that no leak will occur during the fusing of the disc to the glass tube. The specification states that a copper-silver alloy containing 80 per cent. of copper and 20 per cent. of silver is found to be very suitable, and incidentally has approximately the same melting point as that of pure silver. The accompanying illustration indicates how the invention is carried into effect. It will be seen that the usual glass foot *F* is provided with two cylindrical tubes *S*, the ends of which are closed by discs *D* fused on in the usual manner, the leading-in conductor *C* passing through the centre of the discs and being soldered at *X*.



A HIGH-FREQUENCY AMPLIFIER.

(*Convention date* (*France*), *24th August*, 1922. *No.* 210,440.)

L. Levy describes in the above British Patent a form of amplifier which is illustrated by the accompanying diagram. Referring to the illustration it will be seen that the valves *A* and *B* act as high frequency amplifiers, valve *C* as the rectifier, and valve *D* as a low frequency amplifier. An ordinary input tuned circuit is shown at *T*. The patent relates to the method of coupling the high frequency valves, which consists in employing a reactance wound with fine wire, and provided with a movable core of fine iron wire shown at *L* and *F* respectively. The specification states that the coupling devices may be made by winding fine wire into a number of grooves in a fibre or similar tube which



is provided with a movable iron wire core. We should imagine that while being rather stable the amplification would not be very great unless the cores were exceedingly carefully constructed.

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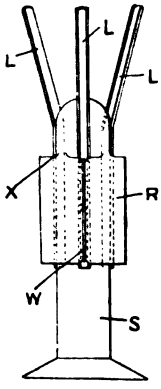
ELECTRODE SUPPORTS.

(*Application date, 12th December,* 1923. *No.* 229,429.)

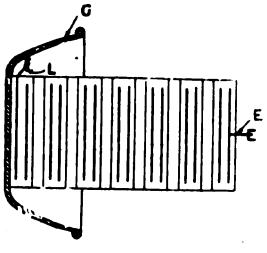
The Edison Swan Electric Company, Limited and T. W. Price describe in the above British Patent a method of supporting electrodes in power valves. Referring to the accompanying illustration it will be seen that the usual stem *S* of glass or silica is provided with a ring *R* of similar material, which is arranged concentrically with the stem, and is fused to it at several points such as X. The supports *L* for the electrodes are passed through the annular space which exists between the ring and the stem. Welded or otherwise fixed to the end of the support *L* is a length of wire *W*, which can also be passed through the annular space, the ends of which are twisted together, and secure the support firmly in position.



A SAFETY DEVICE FOR CONDENSERS.

(*Application date, 16th November,* 1923. *No.* 229,010.)

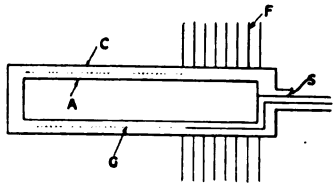
C. Seymour, D.S.O., and W. Ure describe in British Patent No. 229,010 the construction of a condenser suitable for high voltage, high frequency current working. The object of the invention is to produce a condenser such that a more uniform distribution of electric flux exists, thus minimising the possibility of local over-voltage stress in the insulator and consequent failure of the condenser. Referring to the illustration it will be seen that the condenser is built up as usual with metal foil which may be rectangular in shape with rounded corners. This, of course, is the usual practice. One element of the condenser is earthed at *E*, while the other element is connected by a lead *L* to a guard *G* of the shape shown, to which a high voltage terminal is also attached.



AN EXTERNALLY HEATED VALVE.

(*Application date, 22nd November,* 1923. *No.* 229,019.)

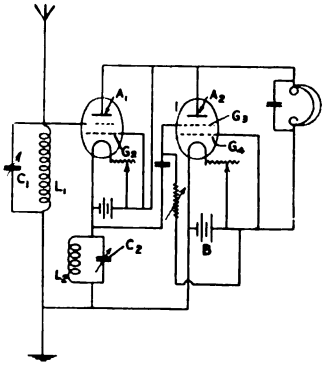
A. I. B. Ghyssaert describes in British Patent No. 229,019 the construction of an externally heated valve which is represented diagrammatically by the accompanying illustration. The object of the invention is to obviate the necessity of using a heated filament as a cathode, and accordingly the inventor proposes to make the cathode in the form of a metallic cylinder closed at each end, inside which the anode and grid are supported. According to this construction it is stated that the cathode can be placed in the fire or heated by a gas flame. Thus in the accompanying illustration the cathode takes the form of a cylinder *C* which may be coated with some barium, thorium, or similar compound. The grid is shown at *G* and the anode at *A*. The cathode is also provided with a number of radial fins *F* for the purpose of cooling it at one end in the neighbourhood of the seal *S*, through which the anode and grid leads pass. It would appear at first sight that the idea would be quite practicable but we should imagine that certain difficulties would arise in practice. In the first place, the inter-electrode capacities would probably be high, and also if used for very high frequencies trouble would no doubt arise owing to eddy currents and other undesirable effects. Another drawback is the fact that if the temperature of the cathode was in the neighbourhood of a dull red heat or even black heat osmosis would occur, and it seems probable that after running for a little while the vacuum would be destroyed.



A FOUR-ELECTRODE VALVE CIRCUIT.

(*Application date, 27th June,* 1924. *No.* 227,364.)

A rather peculiar arrangement of two four-electrode valves is described by Rodo Patents, Limited and F. A. L. Sloot in British Patent No. 227,364. Apparently the object of the invention is simply to provide a means for amplifying signals at radio frequency by two very peculiarly arranged four-electrode valves, which incidentally necessitate the use of two filament batteries. The circuit is shown in the accompanying diagram, and it will be seen that both four-electrode valves are operated at very low anode voltages, which are obtained by direct connection to the positive side of the filament battery, the inner grids also being connected to the positive terminal in order to neutralise the effect of the space charge. It will be seen that there are two tuned circuits *L1 C1*, *L2 C2*, both of which are tuned to the incoming frequencies. The circuit *L2 C2* is connected between earth and the filament of the first valve, while the aerial circuit is connected between the outer grid and the earth. The anode *A1*, inner grid *G2*, and anode *A2* of the second valve, are all connected together. The circuit *L2 C2* is connected by a grid condenser and leak across the outer grid *G3* and the filament battery *B* of the second valve. From the information given in the specification we cannot see how the scheme is intended to work, and we do not see the advantage of using two four-electrode valves and two filament batteries.



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EXPERIMENTAL WIRELESS & The WIRELESS ENGINEER

VOL. II. JULY, 1925. No. 22.

Editorial Views.

Coil Losses.

THE short notes by Mr. R. M. Wilmotte in E.W. & W.E. for May and June, and that by Mr. S. Butterworth in this issue, attract attention to one of the most important problems in wireless, which is also one of the most difficult: that of the losses in, or "effective resistance" of, a coil.

There has been great confusion for a long time as to the point of view from which to regard these losses, but it seems to be clearing up now, although the process has hardly yet spread far from the laboratory.

Roughly speaking these losses may be divided into three sections: Losses from the resistance of the wire to the main current passing through it; losses from the resistance of the wire to currents induced in neighbouring turns and other conducting objects by the main current (the "eddy current" losses); and losses due to the solid insulating matter necessary to support the coil (the "dielectric losses").

It appears to be fully established now that for coils of reasonably good design working at 200-1,000 meters, the most important losses are those due to eddy currents. At extremely long waves the actual resistance of the wire itself preponderates, while at extra-short waves the dielectric losses become important. We must confess that we ourselves have been inclined to over-estimate the importance of dielectric losses at medium frequencies (the broadcast band for example). This is because it is extremely difficult to separate eddy current losses from dielectric losses experimentally, while as a rule the special precautions taken to diminish the latter (careful spacing of wires, etc.) also diminish the former.

There is, however, one possible method, as shown by Mr. Butterworth in this issue: The eddy current losses in a given coil depend simply on the currents in near turns, while the dielectric losses depend on the voltage between near conductors. If we keep the same current in all turns, but vary the voltages between near turns by altering the order of the turns in the circuit, we get a change in the dielectric loss from which could be calculated approximately the total dielectric loss.

Perhaps the most important point for the general user to realise is that the choice of wire dimensions should be governed (as regards all but long-wave coils) almost entirely by eddy-current considerations. The D.C. resistance, or even the H.F. resistance of a similar length of wire straightened out, is not really relevant to the case.

It is unfortunate that the mathematical analysis involved in working out formulæ for these eddy-current losses is to the ordinary wireless enthusiast very advanced. Since, moreover, it still leaves the dielectric losses unknown, few of the "practical" men have as yet given to the eddy-current calculations the attention they deserve. This is undoubtedly a mistake. Apart from anything else, the comparison of calculated eddy-current losses with measured total losses for a wide range of coils should give

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sufficient information about the remaining dielectric losses to allow an empirical formula to be found for them, in which case the design in advance of the best coil for given conditions will become possible.

It happens opportunely that an investigator who has for years specialised in the subject, and is regarded as one of the great authorities on it, has now completed tables by which the design of coils of most types for low eddy-current losses becomes a matter of simple arithmetic. We have recently carried out a series of measurements on various well-known receiving coils, with the object of checking this method against experimental results. The comparison is not yet completed, but if all goes well we hope to publish at an early date the method by which even a beginner can design a coil to fulfil any given conditions with lower losses than anything at present obtainable on the market.

The Tuning of Multi-Stage Sets.

An interesting point came up to us for decision not long ago in connection with the design of a supersonic set. As most of our readers are aware, many such sets use an intermediate amplifier of which the intervalve couplings are practically untuned, or at any rate very flat, except for one at the beginning or the end which is of the nature of a very sharply tuned loose coupling.

The question then arose as to which was preferable: one very sharp and several untuned stages: or several "fairly sharp" stages, the overall selectivity being the same in each case. The only way to solve it seemed to be to calculate out the resonance curves in each case, and on doing so some quite interesting results were found. It is hardly necessary to give the calculation in a special article, since it is in no way out of the ordinary. The result shows that, for an equal ratio of tuned current to that at a frequency well "off-tune," the set with several equal stages gives a curve with a flatter top and steeper sides than that with one extra-sharp stage. It is therefore the superior for supersonic work on telephony, where one needs a flat-topped curve to include the side-bands. On the other hand, a concentration of selectivity in one or two super-efficient circuits is valuable for cases where we wish to amplify an unmodulated input of single frequency.

In American supersonic practice, it is common to refer to such a single sharply-tuned coupling as a "filter." It should be realised that on this side of the Atlantic the word "filter" is used especially for circuits giving a flat-topped resonance curve. It is therefore singularly inappropriate in this case, and should not be used in this country.

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Aerial Tuner Design. [R141

(CONCLUSION).

By W. B. Medlam, B.Sc., A.M.I.E.E., and U. A. Oschwald, B.A.

Case III.—Effect of parallel capacity in a crystal circuit.

The existence of optimum values of parallel capacity for low values of the inductance in the case of a crystal circuit is well shown by the curves in Figs. 16 and 17. In these diagrams crystal current is plotted against inductance for a number of different values of added parallel capacity. The results were obtained by setting a parallel condenser to a fixed value (shown by the figure, indicating μF, against each curve) and retuning on the series condenser

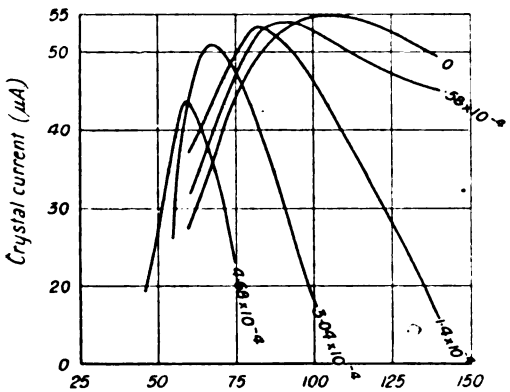

Fig. 16.

as the value of L was altered by stripping turns off the A.T.I. The curves in Fig. 17 refer to a perikon crystal with one pair of 4 000 ohms phones in series with the crystal; those in Fig. 16 refer to the same crystal but with the phones shorted.

It will be noted that with low values of L, the crystal current is increased by parallel capacity so long as this capacity does not much exceed its optimum value. Also, as the inductance is increased, the amount of parallel capacity required to give the maximum current steadily decreases until, for a certain value of L, the best results of all are obtained with no parallel capacity. If L is still further increased the crystal current drops, as was shown in Figs. 8 and 9. The variation of optimum crystal current with parallel capacity is shown separately in Fig. 18.

Effect of Parallel Capacity in a Valve Circuit.

The family of curves in Fig. 19 illustrates the effect of parallel capacity in the case of a valve circuit. In this diagram values of the voltage across the A.T.I. are plotted against L. The figures against the graphs give the values of parallel capacity in microfarads. These curves exhibit the same general characteristics as those in Figs. 16 and 17; that is, they show that both the optimum voltage and optimum inductance increase

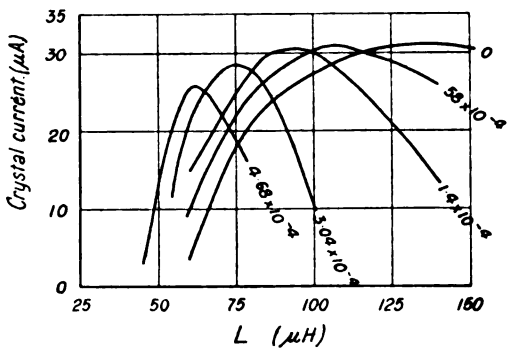

Fig. 17.

as the value of parallel capacity is reduced. The variation of optimum voltage with parallel capacity is shown in Fig. 20. The scale values of parallel capacity are those obtained from the readings of a condenser connected across the A.T.I. Hence they do not include the unavoidable capacities of the valve and the A.T.I. itself. Thus, the real zero of the capacity scale is a little to the left of the marked zero.

Optimum values of L and K, taken from the curves in Figs. 16, 17 and 19, are plotted separately in Fig. 21.

It is interesting to see whether results such as those in Fig. 21 are calculable on purely theoretical grounds by application of the formulæ given above.

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Taking Equation (IV.), and writing the coefficient of ω^2L^2 as a, we have

$$a\omega^2L^2 + 2\omega K_3 . \omega L - 1 = 0$$

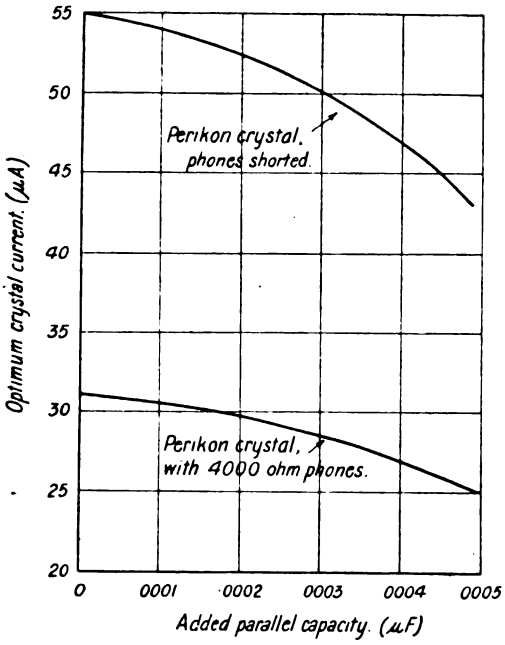

Fig. 18.

from which

$$L = \frac{-K_3 + \sqrt{K_3^2 + \frac{a}{\omega^2}}}{a}$$

where

$$a = \frac{1 - \omega^2 K_3^2 R r_1}{R(r + r_1)}$$

In the case of the valve, the grid-filament resistance, R, under the test conditions, was of the order of 7×10^4 ohms. On 360 metres $\omega = 5{\cdot}2 \times 10^6$, and $\omega^2 = 27{\cdot}4 \times 10^{12}$. Taking an aerial resistance of $r_2 = 40$ ohms, we have

$$a = \frac{1 - .767 \times 10^{20} K_3^2}{7 \times 10^4 (r + 40)}$$

We have to calculate L for a series of values of parallel capacity, K_3. Suppose we make $K_3 = {\cdot}0001\ \mu F = 10^{-10} F$. Then

$$a = \frac{{\cdot}233}{7 \times 10^4 (r + 40)}$$

We have now to choose a value of the coil resistance r. The high frequency resistance of the coils used in these tests was about ·2 ohm per microhenry over the range we are considering. As the value of L is not known we must first assume a reasonable value of r and calculate L. Then we have to correct r to agree with this value of L, finally recalculating L.

As a trial we will take 200 microhenries for the A.T.I. for which $r = {\cdot}2 \times 200 = 40$ ohms.

Substituting this value of r we get

$$a = {\cdot}04 \times 10^{-6}$$

and $L = 177$ microhenries.

As L is lower than anticipated we must reduce the value of r. An inductance of 175 microhenries gives a corrected value of $r = 35$ ohms.

The corrected value of

$$a = 4{\cdot}44 \times 10^{-8}$$

and that of $L = 175$ microhenries. Thus, the change in r has produced no appreciable alteration to L.

Proceeding in this manner, giving various values to K_3, we obtain the results shown in Table II.

TABLE II.

K_3 (μF)	L
0	670
·000 01	515
·000 02	420
·000 1	175
·000 2	106
·000 25	87

These results are plotted in Fig. 22. The curve is in very close agreement with the corresponding experimental curve shown in Fig. 21, reproduced as the dotted line in Fig. 22, after allowing for 25 μμF stray capacity, considering that the values of the resistances taken in the calculations are only approximate.

We will next check a point on the lower crystal curve of Fig. 21, say for a parallel capacity of ·0002 μF. The resistance of the perikon crystal used in these tests was between 15 000 and 25 000 ohms. Taking an average value of $R = 20\,000$ ohms, and a trial value of coil resistance of 9 ohms, the value of L works out to 68 microhenries. The experimental value from Fig. 21 is 75 microhenries, or 76 microhenries after allowing about 30 μμF for stray parallel capacities.

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Variation of Optimum Value of L with Wave-length.

We have not had an opportunity of carrying out any experiments to determine the best value of L for wave-lengths greater than 365 metres, so that the following conclusions are based only on theoretical grounds, and require experimental confirmation.

If we assume the parallel capacity to be low, Equation (VIII.) shows that ωL is constant, provided that the various resistances remain unchanged on altering L and ω.

Thus, if the wave-length (λ) is doubled, ω will be halved, and L will have to be doubled. The aerial capacity required to tune this value of L will also have to be doubled. We have roughly, then, that for maximum efficiency both L and the aerial capacity must be equally increased with λ.

In the case of a valve of low self-capacity, operated with plenty of negative grid bias to maintain a high value of R, and used in conjunction with a tuning coil of minimum self-capacity, the optimum value of L will be in the neighbourhood of 360 microhenries on 360 metres, which suggests the very simple relation

$$L \text{ (microhenries)} = \lambda \text{ (metres)}.$$

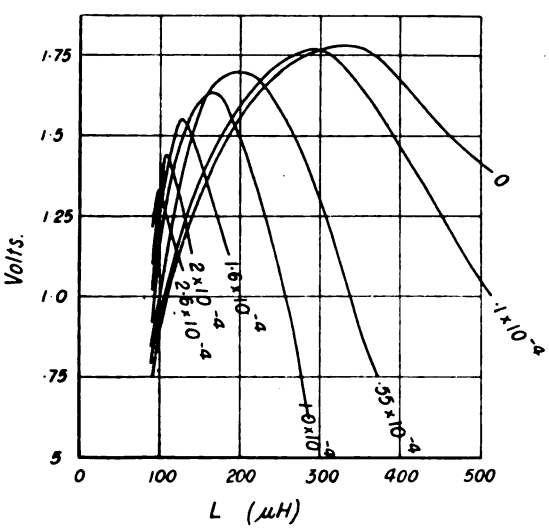

Fig. 19.

The aerial capacity (K) required to tune this value of L will be

$$K\ (\mu\text{F}) = \cdot 28 \times 10^{-6}\ \lambda \text{ (metres.)}$$

For a crystal circuit the corresponding relations are

$$L\ (\mu\text{H}) = \tfrac{1}{3}\ \lambda \text{ (metres).}$$

and

$$K\ (\mu\text{F}) = \cdot 84 \times 10^{-6}\ \lambda \text{ (metres).}$$

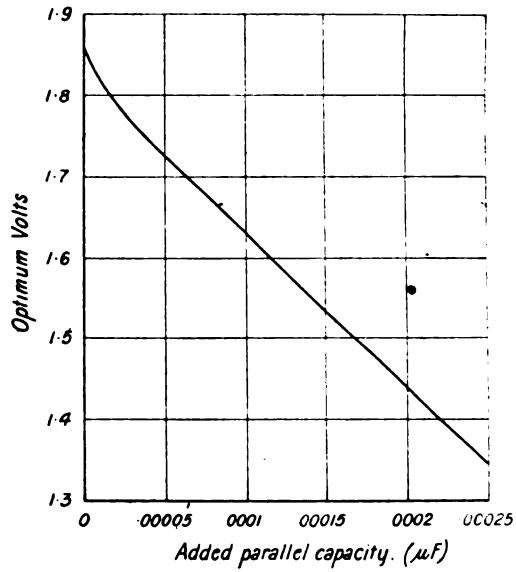

Fig. 20.

The above simple formulæ must be taken as giving only a rough idea as to the best value of L on long waves. To obtain an accurate estimate a number of corrections have to be applied.

(*a*) On long waves the inductance has to be more concentrated, giving greater self-capacity. This tends to lower the optimum value of L. On the other hand, the general formulæ shows that the effect of the self-capacity becomes smaller as λ increases. For example, in one numerical case, a parallel capacity of 25 cm. altered L by 26 per cent. on 360 metres (for a valve), but only by 3 per cent. on 3 000 metres.

(*b*) As the number of turns on the A.T.I. are greater, its resistance will be higher. The effect of increased coil resistance is to increase L.

(*c*) The aerial resistance will be higher, in general.

Correction (*a*) tends to reduce the optimum value of L and (*b*) and (*c*) tend to increase it. As the effect of (*b*) predominates we should expect to find that the simple formulæ given above lead to values of L which become more and more on the low

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side as λ is increased. If this is so it is a fortunate result, for then the aerial capacity required to give the best possible results will not increase so fast as is indicated above. For example, the simple formulæ indicate an aerial capacity of 3 000 metres of about ·000 8μF for a valve, and about ·002 5μF for a crystal set. In favourable situations, using a cage aerial, the former value may be obtainable, but a P.M.G. aerial having a capacity of ·002 5μF would be something of a curiosity.

Effect of Aerial Capacity.

On long waves, then, 100 per cent. results may not be obtainable on account of insufficient aerial capacity, and we have to decide whether it is better to tune on the inductance only, or to tune with a parallel condenser.

Some idea of the relative efficiencies of these two arrangements on long waves may be obtained by considering a numerical

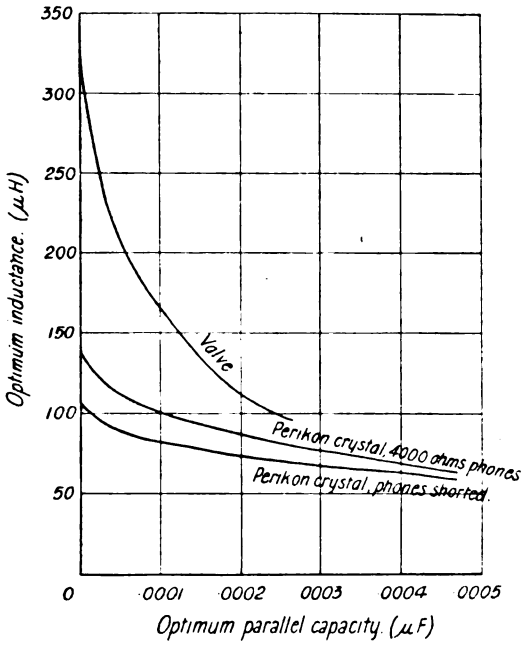

Fig. 21.

example. Suppose we have an aerial of capacity ·000 25μF (K_4), and we tune it to 3 000 metres ($\omega = \cdot 628 \times 10^6$) using various values of inductance and parallel capacity. The resonant voltage rise across the A.T.I. is given by Equation (1). This equation may be put in a simpler form for the purpose of this calculation as the aerial capacity, K_4, is to be kept constant.

From the resonance condition,

$$\omega^2(K_3+K_4)L=1,$$

we have $\quad 1-\omega^2 K_3 L = \omega^2 K_4 L$

Hence we may write $\omega^2 K_4 L$ in place of q in Equation (i.), giving

$$\frac{E_1}{E_2} = \frac{\omega K_4}{\omega^2 K_4^2 r_1 + \frac{1}{R} + \frac{r}{\omega^2 L^2}} \quad .. (26)$$

showing that for a fixed value of K_4, E_1 increases indefinitely as L is increased. Thus plain inductance tuning cannot be improved upon in such a case. To complete our numerical results we will take $r_1 = 15$ ohms, $r = 40$ ohms, and $R = 10^5$ ohms for a valve. Substituting these values, together with those of K_4 and ω, in Equation (26) gives

$$\frac{E_1}{E_2} = \frac{1.57}{.104 + \frac{1.014 \times 10^{-6}}{L^2}}$$

By giving L a series of values we obtain the values of E_1/E_2 shown in Table III.

TABLE III.

$L\mu$H.	$K_3(\mu$F)	E_1/E_2.
10 100	0	13·8
5 600	·000 2	11·5
3 730	·000 42	8·88
1 000	·002 3	1·43

The above results show that parallel capacity leads to loss of efficiency, a ·000 5μF parallel capacity reducing the grid-filament volts by about 50 per cent. For the case of a crystal circuit we will take $R = 5\,000$ ohms, leaving other values unaltered. This gives

$$\frac{E_1}{E_2} = \frac{1.57}{2 + \frac{1.014 \times 10^{-6}}{L^2}}$$

The maximum value of E_1/E_2 approximates to ·78 as L is increased and K_3 is reduced, but the loss of voltage due to a given parallel capacity is very much less than in the case of a valve. The damping may be so great with a low resistance crystal that there may be no resonant voltage rise across the A.T.I.

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We have shown that on 3 000 metres, with the given values of resistance, the best we can do with the ·000 25μF aerial is represented by E_1/E_2=13·8 for the valve, and E_1/E_2=·78 for the crystal. As we increase the aerial capacity the value of E_1/E_2 (for a given parallel capacity) increases until the optimum capacity is reached.

The absolute optimum value of L, given by Equation (VIII.) for zero parallel capacity, works out to 3 730 microhenries for the valve, and 835 microhenries for the crystal, necessitating aerial capacities of ·000 67μF and ·003μF respectively. The corresponding voltages from Equation (IX.) are E_1/E_2= 21·3 for the valve, and 4·76 for the crystal. Thus the optimum aerial increases the grid-filament voltage about 50 per cent. and the voltage across the crystal about sixfold.

Effect of Coil and Aerial Resistances.

In measuring the effect on the grid-filament volts of the size of wire on the A.T.I. many experimenters make their measurements using a fixed value of inductance. The results obtained in this way may give quite a wrong impression as to the real effect of the resistance, and, numerically, the results are of little value as they depend on the particular values which ω, L and R may have during the test. This is clearly shown from Equation (VII.). For example, if the inductance is considerably overwound—as might happen if the experiment is carried out on a small aerial—so that ω^2L^2/R is large compared with $(r+r_1)$, the voltage across the A.T.I. will be largely independent of the gauge of wire, and the experimenter will come to the conclusion that the gauge of wire does not matter much. Another experimenter, choosing a low value of L for his tests, will find that the gauge of wire is of considerable importance, for when ω^2L^2/R is made small compared with $(r+r_1)$, the volts vary inversely as $(r+r_1)$.

To obtain consistent results it is necessary to take an inductance-voltage curve for each gauge of wire, so as to enable the optimum values to be located in each case.

Assuming the parallel capacity to be small, Equation (IX) shows that, with the optimum value of L, $E_1 \propto 1/\sqrt{r+r_1}$. On long waves the coil resistance r will be large compared with the aerial resistance r_1, and E_1 will be inversely proportional to $\sqrt{r}$, thus, wire of the lowest possible resistance is indicated. On very short waves, where r_1 is likely to be several times greater than r, the latter becomes of less importance.

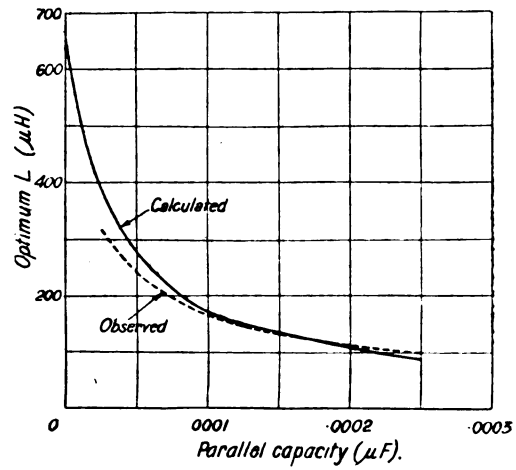

Fig. 22.

In fact, on 100 metres, if the coiled resistance of the A.T.I. is made as high as 1 ohm per microhenry, the voltage will be in the region of 70 per cent. of that which would be given with an A.T.I. of zero resistance. The extra resistance, without doing much harm, adds to the stability of the circuits.

In conclusion, we may perhaps point out that there is a snag in crystal testing similar to that dealt with above in connection with resistance tests. In an aerial test two crystals gave currents of 260 and 150 microamps respectively, with their optimum values of inductance on 2LO—that is current ratios of nearly 2 to 1. On testing, with the same crystal adjustments, on an overwound inductance the currents were 22·5 and 23 microamps respectively. In this case any current ratio between 2 to 1 and unity could be obtained by a suitable choice of inductance.

APPENDIX A.

Relation between the E.M.F. induced in an aerial and the power absorbed. In this paper it is assumed that the E.M.F. induced in an aerial is practically independent of the power absorbed, over the range covered by various resonant circuit conditions, and we present the following experimental results in support of our assumption.

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Method 1.—By connecting our aerial directly to earth through a Duddell thermo-galvanometer, as shown in Fig. 1*a*, we have been able to measure the current, I, due to the E.M.F., E, induced by 2LO's transmission. If the aerial constants are K, L, and r, and the resistance of the instrument is r_1 we have

$$E = I\sqrt{(r+r_1)^2 + \left(\frac{1}{\omega K} - \omega L\right)^2}$$

and the power $W = I^2(r+r_1)$.

The power was varied over a range of about 70 to 1 by altering the value of r_1 from 4 to 400 ohms. For the calculation of E it is necessary to know accurately the K, L and r of the aerial. We are certain of our measured values of K and L, but the measurements of r by different methods give results which are not at all in agreement. However, the desired relation between E and W may be obtained without it being necessary to know the aerial r or L by the following modification of the method.

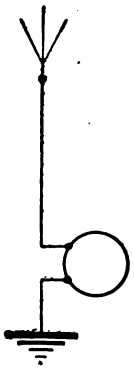

Fig. 1*a*.

Method 2.—Retaining the galvanometer in the earth lead, an inductance and variable condenser of low losses were connected in the aerial circuit as shown in Fig. 2*a*. The galvanometer deflection was read for a series of values of the series capacity K_1, above and below and passing through the tuning point. Let the aerial constants be K, L and r, the instrument resistance r_1, the self-capacity of the A.T.I. k, and its inductance L_1. For the whole circuit, the capacity will be $\frac{KK_1}{K+K_1} + k$; the inductance $L + L_1$ and the resistance $r + r_1$.

The total reactance

$$X = \frac{1}{\omega\left[\frac{KK_1}{K+K_1} + k\right]} - \omega(L + L_1)$$

Let the series capacity at resonance be K_0, then

$$\omega(L + L_1) = \frac{1}{\omega\left[\frac{KK_0}{K+K_0} + k\right]}$$

Hence, the total reactance may be written as

$$X = \frac{1}{\omega\left[\frac{KK_1}{K+K_1} + k\right]} - \frac{1}{\omega\left[\frac{KK_0}{K+K_0} + k\right]}$$

Denoting the total circuit resistance by R $(=r+r_1)$, and the induced voltage by E, then the current I is given by

$$I = \frac{E}{\sqrt{X^2+R^2}}$$

The deflection d of the galvanometer used in this test is proportional to I^2, thus

$$I = a\sqrt{d}$$

where a is a constant determined from a D.C. calibration.

Combining the last two equations and squaring both sides gives

$$a^2 d = \frac{E^2}{X^2+R^2}$$

whence

$$\frac{E^2}{a^2}\left(\frac{1}{d}\right) = X^2 + R^2$$

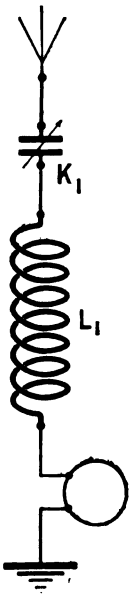

Fig. 2*a*.

Now, on plotting $1/d$ against X^2 a curve will be obtained if E varies with d (and thus with the power absorbed), but a straight line will result if E be constant. So long as numerical values of E are not wanted, values of d and X only need be known, and X involves the measurement of two capacities (K and k) only, and the use of an accurately calibrated condenser for K_1 and K_0.

Numerical results of one test using this method are given in Table I*a*. For this test the circuit constants were: $K = 3{\cdot}9 \times 10^{-10}$F, $k = 10\mu\mu$F, $r_1 = 4{\cdot}25$ ohms, $L = 17\mu$H, $L_1 = 200\mu$H (approx.). For the galvanometer $I = {\cdot}163\sqrt{d}$ milliamps.

The relation between X^2 and $1/d$ is shown graphically in Fig. 3*a*. The scales marked on the diagram refer to the points indicated by X's, the point corresponding to the observation $d = 4.7$ being omitted. To bring in this observation the points are replotted to one-fifth of the marked scales.

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These latter points are shown by dots. Thus the dot and the X marked A represent the same values, *i.e.*, $1/d = \cdot 05$, $X^2 = 21\,304$. Within the limits of experimental error the points lie on a straight line on either scale.

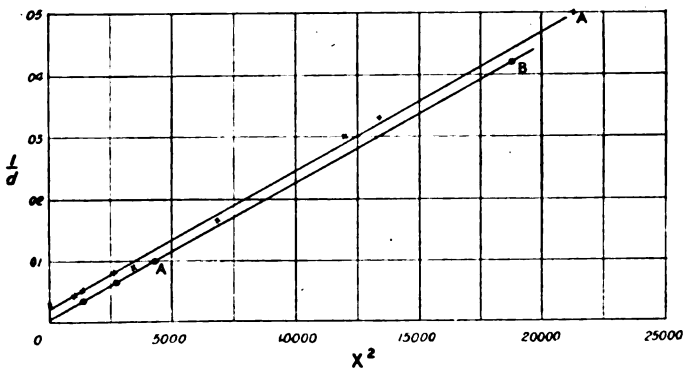

Fig. 3*a*.

As the slope of the two lines is the same it is evident that the point for which $1/d = \cdot 21$ and $X^2 = 93\,150$ (shown at B on the lower line) lies on the upper line produced to about four times the length shown. If there were an increase in the induced E.M.F. when the power absorbed by the aerial were reduced, the points in Fig. 3*a* would lead to a curve which was concave to the X^2 scale. There is no evidence in these results of such a curvature, and if it exists

TABLE Ia.

K_1 $\mu\mu F$	$\frac{KK_1}{K+K_1}$ $\mu\mu F$	$\frac{1}{\omega\left\{\frac{KK_1}{K+K_1}+k\right\}}$ Ohms.	X Ohms.	X^2	d mm.	$\frac{1}{d}$
190	1 277	1 406·5	—208·7	42 600	10	·10
170	1 186	1 505·7	—109·2	11 924	33	·03
166	1 165	1 530·6	— 84·3	7 100	65*	·015 3
162	1 144	1 556·5	— 58·4	3 411	113	·008 85
158	1 123	1 583·2	— 31·7	1 005	230	·004 35
153	1 099	1 614·9	0	0	400	·002 5
148	1 072	1 651·9	+ 37	1 369	200	·005
146	1 062	1 666·4	+ 51·5	2 652	125	·008
142	1 041	1 697·6	+ 82·7	6 840	60	·016 7
138	1 019	1 730·6	+115·7	13 390	30	·033
130	975	1 801·2	+146·3	21 304	20	·05
110	858	2 020·1	+305·2	93 150	4.76	·21

* Off curve.

it is to such a slight degree that it would not affect any of our results based on the constancy of the induced E.M.F.—especially as we require the E.M.F. to be constant only for comparatively small changes of power. The extreme observations in Fig. 3*a* cover a power ratio of about 3 000 to 1. From this set of results we calculate that $R = 37$ ohms and $E = \cdot 12$ volt. Observed values of d and K_1 are plotted in Fig. 4*a*.

In a test using Method 1 the galvanometer current was 319 microamps with a heater resistance of 197 ohms. Taking the aerial resistance as 27 ohms gives a circuit resistance of 224 ohms. The circuit inductance was about 27 microhenries, made up of 17 microhenries for the aerial and an estimated 10 microhenries for the wiring of the circuit. Thus the inductive reactance on 365 metres = 139 ohms. Capacity reactance of the aerial = 496 ohms. The impedance of the circuit

$$= \sqrt{(224)^2 + (496 - 139)^2} = 421 \text{ ohms.}$$

Hence $E = 319 \times 10^{-6} \times 421 = \cdot 134$ volt.

This result is somewhat higher than that given by the other method, but in the calculation we are not sure of the figures given for the aerial resistance and the stray inductance. While an error of 2 or 3 ohms in the aerial resistance makes but little difference to the result in this case, the

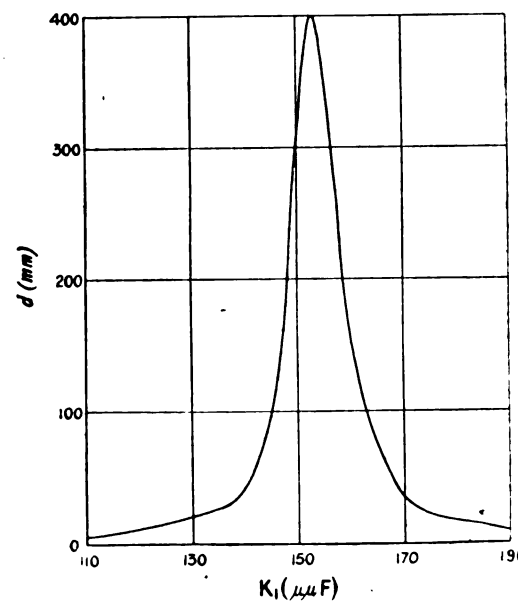

Fig. 4*a*.

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inductance of the wires to the galvanometer (which had to be set up some 12 ft. from the lead-in and earth wires) was important. The figure of 10 microhenries for this inductance was calculated from the area of the loop; and the effects of an iron motor frame within a few inches of the loop had to be ignored. Had the stray inductance been 20 microhenries the value of E wou'd come out to ·115 volt.

APPENDIX B.

Equivalent Load Resistance of Receiving Circuit.

(1) *Input resistance of valve circuit.*—The magnitude of R is fairly easily obtained experimentally for a given valve working under given conditions; but it is quite another matter to give quantitative data applicable to all cases, owing to the large variation of R with the circuit conditions. Its value at a given frequency depends upon the H.T. voltage and filament current, the grid-current, the inter-electrode capacities of the valve, and the nature of the anode circuit.* It also depends on the type of valve holder, the layout of the wiring, and the dielectric loss of the material on which the input terminals are mounted. In addition there is a shunt loss resistance associated with the self-capacity of the A.T.I., although with properly designed coils this resistance may be made much higher than that of a valve under working conditions.

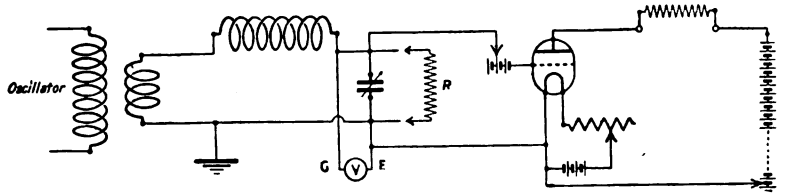

Fig. 1*b*.

The method used for measuring the input resistance is shown in Fig. 1*b*. The valve under test is connected across the condenser of a resonant circuit loosely coupled to an oscillator. The voltage across the condenser (indicated by a thermionic voltmeter V) varies according to the load produced by the valve. For calibration a series of high resistances R were substituted in place of the valve under test, and the resistance required to bring down the reading of the voltmeter to the value obtained with the valve in circuit is taken to be the equivalent input resistance. Each of the resistances used in this calibration consisted of a single straight line of platinum deposited on mica. These resistances were suspended from two stout bare wires mounted on the condenser terminals, so that no extra dielectric loss resistance was added to the circuit with the resistance R. This precaution was found to be necessary with the higher values of R. The results of tests on an R-type valve are given in igs. 2*b* to 4*b*, and Table IB. The peak value of the voltage across the condenser, when unloaded except for the voltmeter, was kept constant in all these tests at 2·2 volts. $\lambda = 365$ metres.

The curves in Fig. 2*b* show the general effect of H.T. and negative bias on the input resistance. Observations for the marked curves were taken with a constant anode load of 35 000 ohms (the resistances used here were those used in the calibration test. They are non-inductive and have a self-capacity not greater than 1$\mu\mu$F). Filament current ·65 amp. A load of 35 000 ohms was chosen as it was approximately that load giving the maximum loss and minimum value of R. The input resistance at the working H.T. voltage for amplifying is seen to be below 15 000 ohms with no bias, and about 20 000 ohms with —3 volts bias. Although the input resistance increases with the bias for a given H.T. voltage, there is no advantage to be gained by increasing the bias much beyond the peak value of the input voltage, owing to the reduction in R due to the necessary increase in H.T. counterbalancing the increase due to the extra bias. With anode loads under 1 000 ohms the input resistance with the correct grid bias and H.T. voltage for amplifying was found to be of the order of 300 000 ohms. The unmarked line in Fig. 2*b* shows the variation of R with H.T. for the valve used as a grid-leak rectifier, with a constant anode load of 8 000 ohms (self-capacity 1$\mu\mu$F). The input resistance is seen to be about 75 000 ohms with 70 volts

* J. M. Miller, *Bulletin Bureau of Standards*, No. 5351.

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H.T. With a suitable condenser across the anode load of the detector valve the input resistance would be considerably higher

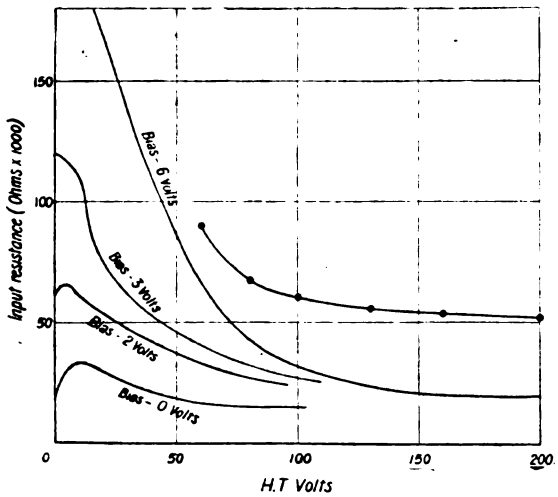

Fig. 2*b*.

than this figure. Results obtained by varying the anode resistance are given in Table I. (col. 2) and in Fig. 3*b*. The curves show clearly the existence of a "worst" anode resistance from the point of view of input load. If the capacity reactance between plate and filament is large, the resultant resistance due to this worst anode load and the internal resistance of the valve in parallel with it is equal to the reactance of the plate to grid capacity. This point is further illustrated in Fig. 4*b*, which shows the general effect of filament current on *R*. The observations were taken with a plate load of 35 000 ohms and 90 volts H.T. The minimum input load resistance occurs near the working filament current of ·65 amp in this case, because the worst plate load of approximately 35 000 ohms was previously determined with this particular current, and this same load was used in the filament current test.

(2) *Equivalent resistance of crystal circuit.*—Before giving the results of high frequency resistance tests on crystal circuits it may be helpful to outline the action of the various parts of a crystal circuit supplied with a modulated H.F. voltage. The circuit is shown in Fig. 5*b*. It contains four elements likely to affect the equivalent resistance, namely, the forward effective crystal resistance r_1, a resistance r and inductance L representing the phones, and a shunt capacity K. First, if K be omitted, and the

TABLE Ib.

Grid bias —6 volts. Fil. ·65 amp.

Anode Resistance (Ohms × 10³).	Input Resistance (Ohms × 10³)	
	H.T. 90 volts.	H.T. 200 volts.
0	425	
2		180
3	190	130
5		58
6	95	
8	65	
10	54	35
25	37	21
56·4	40	21
75	45	22·5
131	56·5	25
530	120	

phones have no self-capacity, the reception of telephony would be impossible, and only a minute rectified H.F. current could flow through the circuit if L had its normal value. Thus some parallel capacity, which may be wholly or partly provided by the

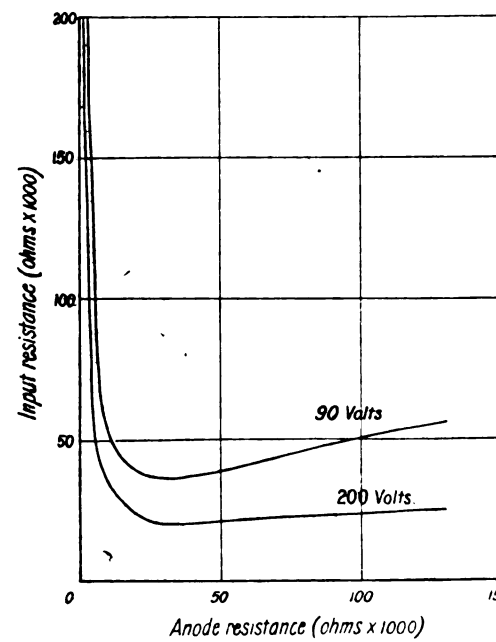

Fig. 3*b*.

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phones themselves, is necessary. From considerations given later it would appear that the necessary capacity in μF should exceed T/r, where T is the time in μ-secs. of one

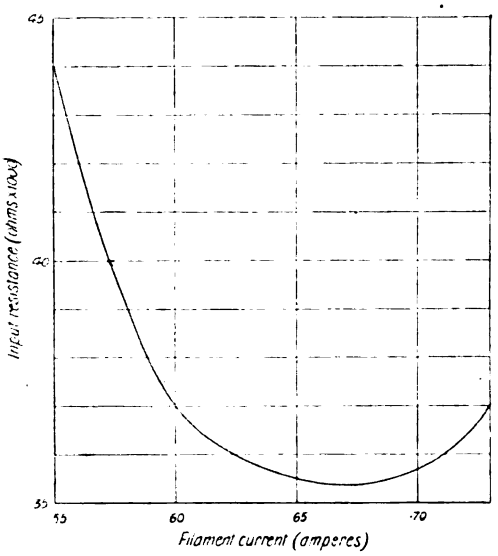

Fig. 4b.

cycle of the H.F., and r is the phone resistance in ohms. Thus, for 2 000 ohm phones on 300 metres ($T=10^{-6}$ secs.), K should exceed $1/2\,000=\cdot000\,5\mu$F, and on 3 000 metres, the minimum value of $K=10/2\,000=\cdot005\mu$F. To be on the safe side the capacity should be made equal to twice the value calculated as above. If a microammeter A, Fig. 5b, is included in the phone circuit it will be found that its reading increases rapidly as K is increased to the value T/r, and then increases more and more slowly as K is further increased beyond this value. In an actual test we have found that an increase in K from ·001 to 20μF (with 2 000 ohm phones on 365 metres) made no measurable difference to the reading of A, and also had no noticeable effect on the load produced by the crystal circuit. But the large value of K killed the L.F. current through the phones. Turning now our attention to L, we have found that the magnitude of the pure inductance —from zero to 100 henries—has no noticeable effect either on the reading of A or on the load resistance of the circuit. The L.F. current, however, decreases continuously as L is increased. Thus, the equivalent resistance R depends only on r and r_1, and curiously, it is often less than either the D.C. or the A.C. resistance of the crystal circuit, and may be less than the phone resistance alone. In explanation of these results, we may suppose the crystal to pass no reverse current, so that, during the forward half-waves of the applied voltage, current starts to flow through the crystal at the instant the applied voltage exceeds the voltage of the condenser, and stops at the instant the applied voltage falls to the same value as that of the condenser. As the average condenser voltage is usually an appreciable fraction of the supply volts, the active period of the crystal is less, in general, than half the H.F. period. Thus, current gets through the crystal in gushes lasting only, say $\frac{1}{3}$ or $\frac{1}{4}$ of a period. The current through r, on the other hand, is continuous throughout the cycle. As the same quantity of electricity, per cycle, flows into the condenser through the crystal as flows out of it through r, it follows that the average crystal current during the active portion of the cycle must be 3 or 4 times the steady current through r, and the actual crystal resistance will be correspondingly lower than its value when carrying the same current as the phones. As regards the phone resistance r, this does not really enter into the circuit as a resistance: it merely controls the mean voltage of K, which in turn regulates the flow of current through the crystal. For example, if r is increased, the rate of leakage from K is reduced, and the voltage of K will be higher than before at the end of the cycle.

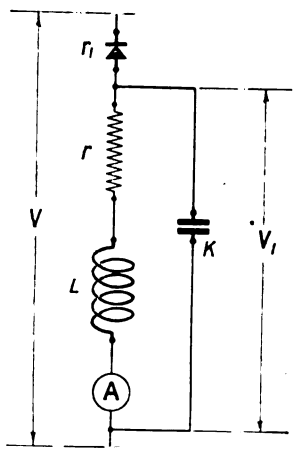

Fig. 5b.

Thus, crystal current can flow only during a smaller fraction of a cycle; it starts later and ends earlier in the cycle. It may be noted that, if the crystal is an imperfect rectifier, the imperfection will have more harmful results than is apparent from a D.C. test, for reverse current flows during

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the whole of the reverse half-cycle and also during the commencement and end of the forward half-cycle while the condenser volts exceed the instantaneous value of the supply voltage. That is, reverse current flows for, say, $\frac{2}{3}$ to $\frac{3}{4}$ of a cycle. In addition, the maximum value of the reverse voltage is the sum of the condenser voltage and the maximum value of the supply volts, instead of the difference between these two voltages as in the case of the forward current. The maximum reverse voltage may easily be three times the maximum forward voltage.

Summing up, we find that the load resistance of a crystal circuit does not depend —at least to any appreciable extent—on K and L; that while it depends indirectly on r, the ohmic value of r is not a part of the load resistance; and that the actual crystal resistance r_1 during its active period must be taken as the value corresponding to a current several times greater than the steady phone current.

Experimental results obtained with a galena crystal are given in Table IIB. The A.C. test was made on 365 metres, the equivalent load resistance R being determined by the method of substitution described above. Measurements of R, the A.C. voltage, V, supplied to the crystal circuit, and the steady current, I, through r, were made with five different values of r. These measurements were repeated for four different input voltages. Also, at the same time, a D.C. test was made on the crystal circuit. The D.C. voltages, E, required to send the same current, I, through the circuit are shown in the fourth column. The input, phone and crystal powers are shown in columns (9), (10) and (11), respectively. In all cases the capacity across r was ·001 μF.

TABLE IIB.

(1) V Volts.	(2) I μ Amps.	(3) r Ohms.	(4) E Volts.	(5) R Ohms.	(6) D.C. Resist. $=\frac{E}{I}\times 10^6$	(7) V_1 Volts.	(8) δV_1 Volts.	(9) $P_1=\frac{V^2}{R}$ μ Watts.	(10) $P=rI^2$ μ Watts.	(11) $P_c=P_1-P$ μ Watts.	(12) α °	(13) I_c μ Amps.
·375	200	30	·21	1 500	1 050	·006	·244	93·7	1·2	92·5		
·76	189	2 030	·593	3 400	3 140	·38	·23	170	72	98·1		
1·03	170	4 030	·90	4 650	5 300	·68	·207	228·5	116·5	112		
1·48	154	8 030	1·46	6 750	9 460	1·24	·188	325	190	135		
1·67	146	10 100	1·68	7 640	11 500	1·47	·178	366	213	153	102°	515
·26	100	60	·147	2 200	1 470	·006	·122	30·7	0·6	30·1		
·375	85	2 060	·317	3 600	3 730	·175	·104	39	14·8	24·2		
·485	78·5	4 060	·467	4 900	5 950	·319	·096	48	25	23		
·67	71	8 060	·733	7 000	10 300	·572	·087	64·2	40·6	23·6		
·77	68	10 130	·843	8 000	12 400	·689	·083	74	46·2	27·8	102°	240
·185	50	60	·117	2 850	2 340	·003	·061	12	0·15	11·8		
·26	44	2 060	·193	3 850	4 400	·09	·054	17·5	4	13·5		
·32	41	4 060	·267	5 000	6 500	·166	·05	20·5	6·77	13·73		
·405	37	8 060	·417	7 250	11 300	·298	·045	22·6	10·9	11·7		
·458	35·9	10 130	·477	8 400	13 300	·364	·044	25	12·9	12·1	112°	115
·125	20	60	·077	2 200	3 850	·0012	·024	7·1	0·024	7·1		
·16	18	2 060	·113	3 600	6 300	·037	·022	7·1	0·65	6·45		
·18	16·8	4 060	·143	4 000	8 500	·068	·021	8·1	1·13	7·0		
·23	15	8 060	·190	5 900	12 700	·121	·018	9·0	1·8	7·2		
·26	14·2	10 130	·217	7 900	15 300	·144	·017	8.6	2·02	6·6	134°	38

Comparing columns (3) and (5) it will be seen that the equivalent resistance of the whole circuit is about equal to the phone resistance, r, when the latter is 4 000 ohms. The value of R is less than r when this exceeds 4 000 ohms, and is greater than r when this is less than 4 000 ohms.

Regarding the necessary value of K, the average voltage, V_1, across K is evidently given by the expression

$$V_1 = rI \times 10^{-6}$$

The quantity of electricity in coulombs drawn from the condenser in one cycle (neglecting reverse crystal current), $\delta Q = I.T \times 10^{-12}$, where T = period of the H.F. supply in μ secs. The average change in condenser volts, δV_1, due to this quantity Q, is given by

$$\delta V_1 = \frac{\delta Q}{K \times 10^{-6}} = \frac{IT \times 10^{-6}}{K}$$

where K is in μF.

In order that the condenser may not run dry before the end of the cycle, and thus

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starve the phones of D.C., we should make $V_1 > \delta V_1$*

$$i.e. \quad rI \times 10^{-6} > \frac{IT \times 10^{-6}}{K}$$

$$i.e. \quad K > \frac{T}{r}$$

In the present test $K = \cdot 001 \mu F$, $T = 1 \cdot 22$ μ secs. Thus, we do not get the best results unless $r > 1 \cdot 22 / \cdot 001$ *i.e.*, $> 1\,220$ ohms. This condition holds except for the cases in which the instrument alone, of resistance 30 or 60 ohms, was in circuit. In these cases the inductance of the instrument probably reduced the current below the value it would have attained had the correct value of K been used. Values of V_1 and δV_1 are tabulated in columns (7) and (8) of Table IIB. It will be noted that δV_1 is only about 12 per cent. of V_1 when $r = 10\,000$ ohms; and apparently exceeds V_1 only in the particular cases mentioned above in which the instrument alone was across K. In these cases δV_1 does not really exceed V_1. As K is insufficient to store the full quantity of electricity passing through the crystal the excess flows directly through the impedance of the instrument.

The time interval during which the crystal is active and the average crystal current during this interval may be approximately estimated in a number of ways. Probably the most direct method is to determine the instants at which the supply voltage rises above, and falls below, the condenser voltage. Assuming a sine wave of supply voltage,† the maximum input voltage is $1 \cdot 41 \times$ R.M.S. voltage V, and the instantaneous voltage

$$e = 1 \cdot 41 V \sin \omega t$$

Assuming the fluctuation of condenser voltage, δV_1, to be small compared with V_1, the crystal current starts and finishes when $V_1 = e$, *i.e.*, at instants given by

$$\omega t = \text{arc} \sin \frac{V_1}{1 \cdot 41 V},$$

and the angle, $\alpha°$, during which the crystal is active, will be

$$\alpha = 180 - 2 \text{ arc} \sin \frac{V_1}{1 \cdot 41 V},$$

if we take the smallest value of $\text{arc} \sin \frac{V_1}{1 \cdot 41 V}$ in degrees. In the present test this formula is applicable, with any degree of certainty, only to the cases in which $r = 10\,000$ ohms. With smaller values of r the magnitude of δV_1 was too large compared with V_1 (owing to the low value of K). When δV_1 is large the crystal current starts and also finishes earlier in the cycle, and the active arc may be somewhat different from that given by considering the average value of V_1.

Knowing the active period t of the crystal the average crystal current, I_c, is calculable from the equation

$$I_c = \frac{IT}{t}$$

Values of $\alpha°$ and I_c are given in the last two columns of Table IIB. The peak values of crystal current work out to somewhat over four times the steady phone current I, and the average values are, roughly, three times I.

* δV_1 is the average and not the maximum voltage change. Thus, to be on the safe side, K should be made equal to twice the calculated minimum value.

† A discontinuous load, such as that provided by a crystal circuit, might be expected to cause distortion of the applied voltage wave. We have some experimental evidence that such is not the case. The crystal load appears to diminish the amplitude of the applied voltage wave without affecting its wave form. The amplitude is reduced to the same value in both halves of the wave. The evidence on which these statements are based cannot be given here.

An Acknowledgment.

In our last issue we published two photographs of the new wireless installation at Basle (Switzerland) Aerodrome, but omitted to mention that both the transmitting and receiving plant were by Marconi's Wireless Telegraph Co., Ltd. The photographs also were supplied by Messrs. Marconi.

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The High-Frequency Copper Losses in Inductance Coils.

By S. Butterworth, M.Sc. [R382·1

IN the issue of E.W. & W.E. for May, various writers have made suggestions as to what is the correct basis upon which to design inductance coils suitable for reception throughout the broadcasting range of wave-lengths, and the general impression gathered seems to be that the main losses in these coils are due to the imperfections of the dielectric surrounding and supporting the wires, spacing being resorted to in order to reduce these losses.

Now, although adequate spacing will no doubt reduce these losses, yet it will be shown that with a reasonably good dielectric these losses contribute only a small amount to the total resistance even when the turns are fairly close together. The reason why a proper spacing brings about a considerable reduction in resistance is made clear by a short consideration of the *copper* losses in the coil.

If first we consider an inductance coil through which a *low* frequency alternating current is passing, the main loss in the coil is that due to the direct current resistance of the wire, and everything is to be gained by making the section of the wire as large as possible, that is, by winding the coil closely with thick wire.

But in addition to this loss there is another copper loss. Each turn is situated in the magnetic field due to all the remaining turns, and since this field is alternating, eddy currents are induced in the turn in question in exactly the same way as the eddy currents induced in neighbouring metal objects. The losses due to these eddy currents differ from those due to the main current in that they increase with the diameter of the wire, while the ordinary D.C. resistance diminishes as the diameter of the wire is increased.

Now, if the frequency is increased the eddy current losses grow more rapidly than those due to the main current flowing in the wire, and a stage is reached when they become the predominating factor in the alternating current losses. It then becomes profitable to diminish the section of the wire (keeping the same total winding space and number of turns, so as to hold the inductance constant) as a considerable reduction of eddy current loss may then be obtained, which more than counterbalances the resulting increase in the main current loss. The minimum copper loss is obtained when the diameter of the wire is such that the two losses are about equal. This diameter will of course depend upon the frequency for which the coil is to be designed.

It is possible to obtain formulæ for the two types of copper losses. Thus, four years ago, the writer published formulæ for calculating the copper portion of the resistance of single layer solenoids and disc coils which are applicable for all wave-lengths exceeding about three times the natural wave-length of the coil and for any solenoid having a length not greater than its diameter.

More recently, Professor Fortescue has given corresponding formulæ suitable for deeply wound inductance coils, which are applicable over a wide range of frequency. Unfortunately these formulæ only hold for coils having a winding length which is greater than the overall radius, so that the usual type of commercial wireless receiving coil is not included. The writer however has, for his own use, calculated the necessary factors for these shorter coils, and has generalised Professor Fortescue's formulæ so as to be applicable over the same range of frequency as the single layer coil formulæ referred to above. He hopes to be able to publish this generalisation when sufficient confirmatory or contradictory experimental evidence has accumulated.

It may be stated, however, that the formulæ have been tested by comparison with the measured values in the case of a well-known series of commercial inductance coils for which the inductances ranged from 80 to 2 000 microhenries, and it was found that the calculated copper losses lay between 82 and 92 per cent. of the measured losses at

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wave-lengths for which the coils are normally used.

As regards single layer coils, considerable experimental evidence is available, and in the great majority of cases the ratio of copper loss to total loss in a resonating circuit containing a good quality air condenser is between 0.7 and 0.9. A few comparisons have also been made in which the measured resistance did not include any condenser loss, and these gave agreement with observation within the probable order of accuracy of measurement.

The evidence therefore is all in favour of design which aims at making the total copper loss a minimum. Since there is a correct diameter of wire to make the copper loss a minimum, it is useless to suggest an alteration in this diameter in order to bring about a reduction in the already small dielectric loss.

In the issue of E.W. & W.E. referred to above, Mr. R. M. Wilmotte contributed an excellent article on the Parasitic Losses in Inductance Coils, and gave a short table of measured resistances for a single layer coil at a wave-length of 300 metres. Although these measurements were primarily intended to illustrate the effect of reducing the quality of the dielectric, yet they supply sufficient evidence to emphasise the real proportion of copper to other losses when the dielectric is in a normal condition. We append here the data necessary for the present analysis.

Coil.—Single layer wound on square frame of 7.5 cm. side.
Turns.—30.
Winding pitch.—1.5 mm.
Wire diameter.—0.711 mm. No. 22 S.W.G.
D.C. resistance.—0.405 ohm.
Inductance.—Not stated, but found by known formulæ to be about 77 microhenries.
Self capacity.—Not stated.

MEASURED A.C. RESISTANCE AT 300 METRES.

Condition of Insulation.	Type of Insulation.			
	Bare.	D.S.C.	Enamel.	D.C.C.
Dry	1.58	1.58	1.61	1.64
Wet	1.68	2.09	1.71	4.09

This coil has a remarkably low resistance for its inductance and the length of wire employed.

Except for the fact that the coil is square, the specification conforms almost exactly to the coil I recommended in my paper on single layer coils, viz.: that the coil should have a winding length something less than its radius and a winding pitch twice the diameter of the wire. No one, apparently, has hitherto troubled to test this out. It is seen that the winding pitch of Mr. Wilmotte's coil is nearly the correct one, while, since the equivalent circular coil has a radius of 4.26 cm. and the winding length (30 × 0.15) is 4.5 cm., the coil length is somewhat greater than its radius. However, since the variations of resistance are very slow in the neighbourhood of the minimum conditions an *exact* fulfilment of the conditions is unimportant.

We can estimate the magnitude of the copper loss in the coil by calculating the loss in the equivalent circular coil. The writer's formula for the A.C. (copper) resistance of single layer short solenoids with the wires *well spaced* is

$$R' = R\left\{1 + F + \left(3{\cdot}29 + \frac{b}{2}\right) - \frac{d^2}{D^2}G\right\}$$

where R' is the A.C. resistance,
R is the D.C. resistance,
d is the diameter of the wire,
D is the winding pitch,
b is the coil length,
a is the coil radius,
f is the frequency,

and F and G are tabulated functions of $d\sqrt{f}$.

For the stated frequency and diameter of wire

$$1+F=3.08, \quad G=1.27.$$

The equivalent circular coil (that is, the circular coil having the same winding length, turns, and inductance) has

$$a=4.26, \quad b=4.5,$$

while

$$d=0.711, \quad D=1.5.$$

Inserting these values in the formula we find that the total A.C. copper resistance is 4.32 times the D.C. resistance.

Now the equivalent circular coil requires a shorter length of wire than the square coil and its calculated D.C. resistance is 0.343 ohm. Hence the A.C. copper resistance is 1.48 ohms.

This estimate is admittedly approximate, but when we remember that the A.C. resistance of the wire of the square coil when

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straightened out would be 1.18 ohm, the above value cannot be much too great. There is therefore only about 0.1 ohm left to account for when the coil is dry.

It is unfortunate that Mr. Wilmotte did not state the self capacity so that an estimate could be made of the power factor and self capacity corrections given in his formula.

Mr. Wilmotte's method of illustrating the effect of the dielectric on the losses by applying moisture is interesting, but a much more powerful method may be applied which has the advantage that the dielectric may be studied in its normal dry condition. The method consists in winding the coil in a number of separate sections, of which the ends are brought out and connected in various ways so that in all cases the current circulates in the same direction round the coil, but the potential difference between contiguous sections may be varied. By this means the self capacity, and therefore the dielectric losses, may be subjected to large variations while the inductance and copper losses remain practically constant.

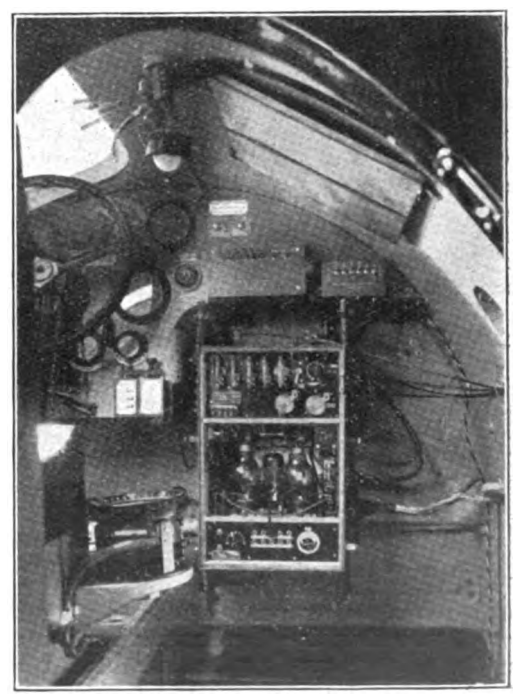
The writer constructed a single layer coil of this type some years ago and the following experimental results may be of interest. The coil was wound on a waxed wood former of 17.5 cm. diameter to a total length of 6.7 cm. with (in the following tests) No. 24 S.W.G. D.C.C wire. The total number of turns was 102, and the coil was broken at the centre into two sections having 48 and 54 turns respectively. The free ends were brought out to two extra terminals. Calling the normal terminals of the coil *A B* and the central terminals *C D*, it was found that when the terminals *C D* were shorted and the terminals *A B* used as the current terminals so that the coil was working in its normal manner, the inductance was 2070μH, the self capacity 11$\mu\mu$F, and the resistance at a wave-length of 1 730 metres was 11.7 ohms.

When, however, the terminals *A B* were shorted and the terminals *C D* used as the current terminals, so that the full potential drop in the coil was thrown across contiguous turns, the inductance was still 2070μH, but the self capacity rose to 93$\mu\mu$F and the effective resistance to 36 ohms.

In this case, the proper formula to apply in order to correct for self capacity and dielectric loss is

$$\text{Effective resistance} = \frac{R' + \omega^3 L^2 C P}{(1 - \omega^2 LC)^2}$$

where ω is 2π times the frequency, L is the inductance, C the self capacity, P the power factor of the dielectric and R' the A.C. copper resistance. Now the theoretical formula makes the copper resistance equal to 8 ohms. This may be a slight underestimate as the coil is rather closely wound, but as we are concerned with the difference between the two cases this does not matter. Multiplying the measured effective resistances by the value of $(1-\omega^2 LC)^2$ appropriate in each case and then subtracting 8 ohms, the portion of the resistance unaccounted for is 3 ohms in the normal and 13 ohms in the abnormal case. The difference, 10 ohms, is due to the power factor of the added self capacity, and is accounted for by a value of P equal to 0.023, which appears quite normal for this type of dielectric. As regards the coil when used in the normal manner, if we assume that the whole of the normal self capacity is due to distributed condensers having the above power factor, the dielectric loss cannot contribute more than 1.3 ohms to the measured resistance at this frequency.



A Marconi A.D.6 telegraph and telephone transmitter and receiver as installed on an Imperial Airways' Machine.

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It will be noted that if we assume the power factor of the dielectric to be invariable with frequency, the dielectric loss introduces into the resistance a term varying as the cube of the frequency. Now the writer, although he has met with experimental formulæ involving square roots, first powers, and squares of frequency, has never met an experimental analysis which requires a power of the frequency as high as the cube. We are therefore forced to assume either that the power factor diminishes with frequency or that the dielectric losses are unimportant. The former assumption seems to be ruled out in view of the experimental evidence on dielectric losses quoted by Mr. Wilmotte.

The case is different if the coils are used at frequencies getting near to the resonance frequency of the coil, as then a considerable fraction of the total current will pass along the capacity paths, but a receiving coil is very seldom required to be used at such frequencies.

Practically the whole of the criticism launched against the utility of the copper loss formulæ turns out on examination of the experimental evidence offered to apply only to the case of large transmitting coils, where by reason of the greater volume of copper employed the copper losses are reduced to a negligible figure. The evidence given in this paper should be sufficient to show that for receiving coils of the sizes usually employed the copper losses are the predominant factor unless the insulation is rankly bad or the current is led through the coil turns in an obviously unsound order. Advice on the choice of the dielectric and on the order in which the current shall pass through the turns is very desirable, but "design" is only beginning and not complete when these points have been settled. The formulæ referred to above enable a complete scheme of design to be worked out and a very close estimate to be made of the resistance for an inductance coil of the type used in reception.

References.

A short list of the more recent papers dealing with the theory and measurement of copper losses is appended for those readers who wish to pursue the matter further.

HOWE.—"The High Frequency Resistance of Wires and Coils."—*Journ. I.E.E.*, Vol. 58, p. 152, 1920.

FORTESCUE.—"The Design of Inductances for High Frequency Circuits."—*Journ. I.E.E.*, Vol. 61, p. 933, 1923.

HICKMAN.—"The Alternating Current Resistance and Inductance of Single-layer Coils."—*Bulletin Bureau of Standards*, Vol. 19, p. 74, 1923.

BUTTERWORTH.—"On Eddy Current Losses in Cylindrical Conductors and Short Coils."—*Phil. Trans. A*, Vol. 222, p. 57, 1922.

BUTTERWORTH.—"Note on the Alternating Current Resistance of Single-layer Coils."—*Phys. Rev.*, June, 1924.

BUTTERWORTH.—"On the Alternating Current Resistance of Solenoidal Coils."—*Proc. Roy. Soc. A*, Vol. 107, p. 693, 1925.

BREIT.—"The Self Capacity of Short Coils."—*Phys. Rev.*, Vol. 17, p. 649, 1921.

BREIT.—The High Frequency Resistance of Inductance Coils."—*Scientific Paper, Bureau of Standards*, No. 430, 1922.

The first two papers treat the subject in a fairly elementary manner and certain approximations are necessarily made. The remaining papers are more mathematical, but the more elaborate formulæ developed therein are necessary not only to justify the simplifying assumptions made in the elementary treatments, but also to fill in gaps where the elementary treatment fails. Breit's two papers are noteworthy as they form the first serious attempts to deal with the distributed self and earth capacities of short coils. They are difficult to read, but the writer believes that the conclusions are reasonably sound.

Low-Power Experiments at 6QB.

By L. H. Thomas. **[R401·22**

A record of some rather remarkable results achieved.

THIS article has been written with the object of encouraging those readers who despair of getting satisfactory results from a transmitter because they have no A.C. available and cannot run a generator. It is also intended to show that some really useful work may be done although conditions seem almost hopeless.

The writer cannot possibly obtain an A.C. supply, on account of a contract held by the gas company, and as the "den" is at the top of the house, a generator, or even a T.V.T. unit would be very inconvenient. The first experiments were therefore conducted with an input of .15 watts from 60 volts in pocket-lamp batteries. With an

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aerial 70 ft. by 28ft., very badly screened, and an ordinary "water-main" earth, reports on the C.W. were received from a distance of 20 miles, although the aerial current could not be read with a 0.5 amp. H.W. meter.

This was encouraging, so the H.T. was increased to about 150 volts (36 pocket-lamp batteries in all). With this, using the reversed feed-back circuit with extremely inefficient inductances, an aerial current of .14 amp was obtained, the valve used being a French "R" with its filament slightly overrun. A report was immediately received from Paris reporting C.W. signals R3 on one valve.

At this the writer determined to see how efficiency could be increased, for if Paris could be reached with an input of 1.2 watts and everything as inefficient as it was humanly possible to make it, better things might obviously be hoped for!

First, a counterpoise was erected. It was seven feet high, and a diagram is shown (Fig. 1). The situation is not exactly ideal. The aerial current was increased and the transmitter rendered much more stable by this arrangement, although the capacity of the aerial system was increased.

The next step was to dispose of the old inductances, which were wound on 8 in. cardboard formers with 7/22 copper. Two helices were therefore wound with $\frac{1}{32}$ in. copper strip on ebonite crossbars, and put into service. An enormous increase resulted from this reduction of the tuner losses, and the space occupied by the transmitter was reduced by about 70 per cent.! Up to this point the circuit in use was still the reversed

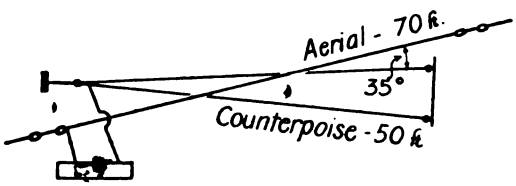

Fig. 1.

feed-back; but the Hartley was now tried, and it seemed to be better suited to the radiating system. The circuit was now as shown in Fig. 2.

The R.F. choke was an ancient duolateral coil of relatively high self-capacity, and yet it gave better results than any of the numerous single-layer coils specially wound for

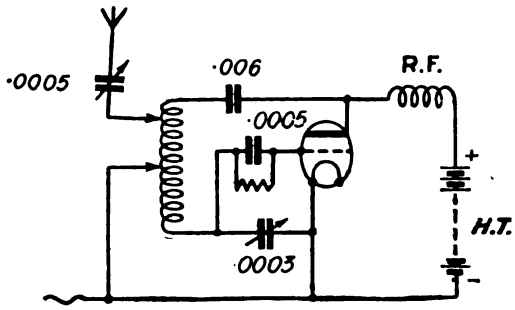

Fig. 2.

the purpose. The grid-leak was the secondary of a power transformer.

The next event of interest was the burning-out of the French "R," which obviously disliked 6 volts. As there was a test arranged for that night, a feverish search was made, which resulted in the use of a D.E.R., with a filament voltage of 2.5. This gave an aerial current of .26 amp on 1.3 watts input, and is still in use. The writer has not yet succeeded in finding its saturation point, and its emission is still perfect although it has had 600 volts (from a spark coil) on its plate.

Reports on C.W. transmissions were now received from Luxembourg, Italy, Denmark and Sweden, and many N. British amateurs worked. The H.T. was then increased once more to 250 volts, and with this voltage, and a plate current of 15mA (making an input of 3.75 watts) and the *same* D.E.R., a report was received from Brooklyn, N.Y. This has been fully confirmed, and the signals are stated to have been received at R4 on a superheterodyne. The time was 22.30 GMT, and the wave-length 150 metres. Finnish 2NCA also reported signals from 6QB as R8 on the same night.

In conclusion, the writer is always glad of reports from any distance, as the power used here has never yet exceeded 4 watts—and is never likely to!

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The Perfect Set.

Part X: More about Reflex Circuits. [R342·4

A detailed examination of a typical reflex circuit which embodies the results of experiments over a long period.

IN our last part we made some general remarks about reflex circuits. This month it is proposed to deal in detail with one typical circuit: that shown last month, and illustrated again, in slightly fuller detail, in Fig. 1 herewith.

We will deal with it bit by bit, giving, as far as possible, reasons for any definite values assigned to the components. This circuit is shown, as an example, for two valves, but may obviously be extended to more, and altered in various ways without change in principle.

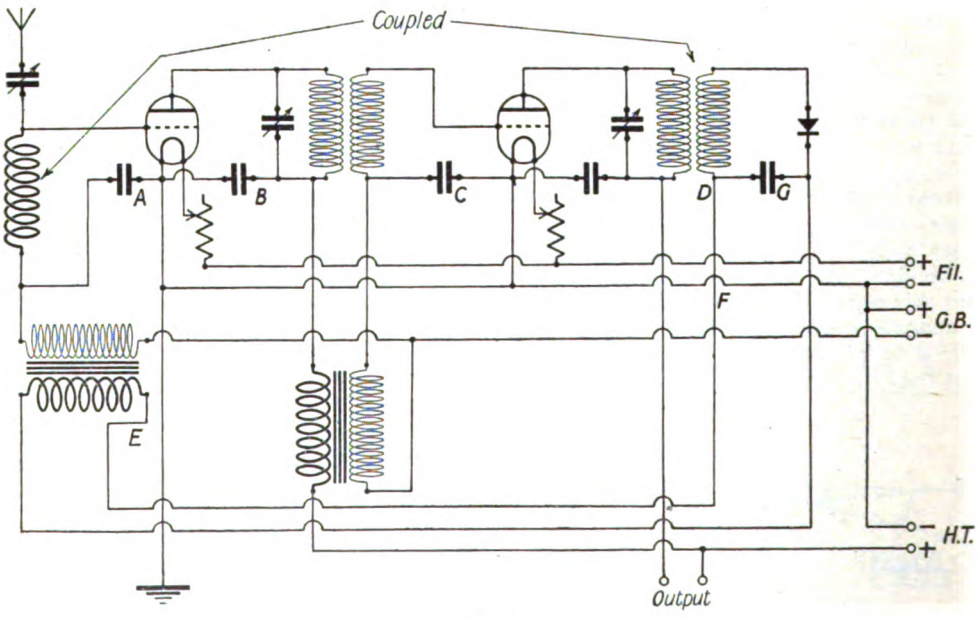

Fig. 1.

Taking the filament circuit first, there are only two noteworthy points. Firstly, the filament rheostats are in the positive lead—in our opinion the only place for them. It is a favourite device of the semi-skilled to try and avoid a grid battery by putting the rheostat in the negative lead, but it has two grave disadvantages: the bias obtained is often insufficient; and every change of filament heat also alters the bias, whether this is desired or not. It is much better practice to do as we have done here.

Secondly, though it is not really a matter of the filament circuit itself, the H.T. is connected to filament negative, not positive, the negative side of the filament being a regular "omnibus" lead taking all returns. This is a great practical convenience, and also makes it simpler to work from the characteristic curve of the valves used. It has the minor disadvantage of needing two or three volts extra of H.T. battery, but we regard this as by far the lesser of two evils.

In the aerial circuit the first point for consideration is the value of the condenser *A*. It will be seen that the connection of the earth to filament negative (a great help to

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stability) puts this condenser into the aerial circuit. As stated in the last instalment, it should be kept small in sets for telephony to avoid unduly lowering the tone by interfering with the action of the L.F. transformer. For all wave-lengths from 200 to 600, it will be found that .000 1μF is a suitable value. This allows of tuning with an inductance of convenient size, and at the same time produces only a quite unnoticeable lowering of tone. A useful rule for longer wave-lengths is to divide the proposed wave-length by 500, take its square root, and put three 0's in front of it. Thus for 1 600 metres we have 1 600 ÷ 500 = 3.2 ; the square root is 1.8 approximately, so the condenser A should be .000 18—say .000 2.

The actual tuning of the aerial circuit can be done in any way desired. The writer prefers a series condenser, as shown, but usually has a series-parallel switch for use if required. If it is not desired to react on to the aerial, a variometer can be used, together with wave-traps, rejectors, loose-coupled circuits, or whatever the user may prefer. Note, however, that if a loose-coupled circuit is used, it is an advantage to link the earth terminal across to the filament negative. The L.F. part of the circuit will be dealt with later.

The Intervalve Coupling.

The main item here, of course, is the transformer. We have already, in the part of this series dealing with H.F. amplification, described our favourite type, and little further remark is necessary. It might be noted that with a close-coupled transformer the tuning condenser may be across primary or secondary. We have often seemed to get better signals with it across the secondary, but this has not yet been confirmed by measurement. When, as is usual, a step-up transformer is being used (1 to 1½ or 1 to 2 is best), there is a slight disadvantage in having the condenser across the secondary, as its stray capacity—when set at zero—has a much larger effect (four times with a 1 to 2 transformer) in shortening the range of wave-length, than when across the primary.

The values of the by-pass condensers B and C also need a little thought. Their design is based, as was that of A, on a compromise between the H.F. and L.F. requirements. In this case, however, we have the fact that B and C do not, like A, form part of a tuned circuit. A little difficulty is that in order that B and C may each have the same effect on its own circuit, B should be s^2 times C, where s is the step-up ratio: but of which transformer? Theoretically, of both; but this is obviously impossible, for the H.F. transformer should not as a rule be more than 1 to 2, while the L.F. will probably be 1 to 4. Actually, it is our usual practice to take about the average, and for broadcast wave-lengths or less to make B ten times C, using .001 and .000 1 for them. Actually it seems to matter little whether B is as low as .000 2, or as high as .002 ; but above this latter value it sometimes begins to lower the tone if music is being received.

The question of stabilising may be considered now. As far as our experience goes, any method may be used if required, and reference should be made to the earlier articles (already mentioned) on H.F. amplification. We have not, however, tried any except neutrodyne condensers—which did not seem very effective—and shunt or series resistances either across or in series with the tuning condensers.

The Detector Circuits.

Bearing in mind that the input resistance of a detector is of the order of 5000 to 10000 ohms for galena, or less when the applied voltage is fairly large; while the output resistance of a valve will be at least 20 000 ohms, as a rule we see that efficiency calls for a step-*down* transformer between valve and crystal, about 1½ or 2 to 1 being correct. Actually, however, we often use a 1 to 1 ratio, which has the advantage of causing the crystal to damp the oscillating circuit rather heavily, and so assist stability. In this case, one need not use two separate windings at all, simply tapping the crystal circuit across a single "tuned anode" coil, which replaces primary and secondary of the transformer. If, however, the set is to be used for long waves, the inductance is likely to be so large that a transformer of the proper ratio will be preferable.

It will be noticed that when the transformer is used, the system consisting of transformer secondary, crystal and condenser, and L.F. transformer primary, is completely isolated. It steadies the set if this is avoided, which can be done in various ways. Some part of the lead DE should be

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connected to part of the set which is approximately at earth potential for H.F. currents: the primary and secondary of either the H.F. or the L.F. transformer may be linked at their low potential ends, or some point on *DE* may be connected to the common L.T. lead, which can be done by making a join instead of a cross-over at the point *F*.

When a tuned-anode coil, and not an H.F. transformer, is used before the crystal, remember that the steady anode current flows through it and sets up a D.C. voltage across it. For long waves, where this coil is large and has a fairly high D.C. resistance, this may be large enough to affect the crystal, and in such cases it is useful to insert a reversing switch as in Fig. 2, so that the crystal can be used either way round.

Next, as to the value of the condenser *G*. This, of course, is simply the condenser which ought to be found in every crystal set, but is often omitted in the hope that the phone leads will have sufficient capacity. In this case also it *may* be omitted if the primary of the first L.F. transformer has sufficient self-capacity. But it is very bad practice to do so. Any H.F. voltage which may be applied to the primary will probably be transferred by capacity coupling to the secondary, thus appearing in the grid circuit of the first valve and upsetting things. Such H.F. voltages can be kept down by making condenser *G* so large that it offers only a low impedance to H.F., and for this reason we make it as large as we dare without risk of upsetting the L.F. performance of the transformer. If, as is usual (see below), this transformer is of high ratio, it will probably stand quite a large condenser across its primary, and we are using, at the moment, .001μF for *G*. If this gives a muffled tone with some other type of transformer, it can be reduced to .000 3: below this there are distinct reaction effects at broadcast wave-lengths. For other wave-lengths adopt the same principle as already described in connection with the other by-pass condenser.

Reaction, if required, is simply arranged for by placing the aerial coil and the crystal transformer or coil so that they can be coupled together. It will be found to work quite smoothly and sweetly until the set oscillates, when there will probably be a loud howl.

The L.F. Side.

From this point onwards we are dealing with audio frequencies. The first point arising is obviously the ratio of the "throw-back" transformer. The particular connections do not affect it: it is simply to be considered as a crystal-to-valve transformer, and its ratio is governed by the impedances in its input and output circuits. Reference to our earlier instalments on L.F. amplification will bring to light a simple approximate rule for the ratio when a valve-grid circuit is across the secondary: divide 250 000 by the impedance in the primary circuit, and take the square root.

Now F. M. Colebrook has shown in "The Rectifying Detector" (E.W. & W.E., May, 1925) that the galena crystal has a quite low output resistance—below 500 ohms. This would give, for the ratio, the square root of 500, or about 20 to 1. But in practice the self-capacity of the windings, and other difficulties, limit the ratio. We have found that 8 to 1 is considerably better than 6 to 1, but that 10 to 1 is little better when commercial transformers are being used. Perhaps an expert might design a suitable transformer of higher ratio, but we have not yet come across one. There is another reason why it is perhaps best not to push the ratio too high where telephony is concerned. This is, that with an 8 or 10 to 1 ratio the transformer has a much higher input impedance than the crystal resistance, which, as also shown by Colebrook, leads to freedom from distortion. So, taking all things into consideration, we can just use the highest-ratio transformer obtainable on the market in the make preferred by the user, 1 to 8 or 1 to 10 being best if obtainable. This is for galena. If perikon, with its higher resistance, is used, then probably 1 to 6 or 1 to 8 will be best.

One transformer secondary lead goes to the grid bias battery, and naturally raises the question of the bias required. This, however, has already been dealt with in an earlier article of this series ("L.F. Amplification"), and the only remark to be added here is that it is occasionally necessary to increase the bias to cover the H.F. components of grid voltage. In the particular set illustrated in Fig. 1, we could calculate as follows, calling the input voltage 1 unit: the H.F. input to second grid is $1 \times \mu$ of first valve $\times$ step-up of H.F. transformer; but

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a deduction must be made for the well-known losses in H.F. amplification. At broadcast waves, with a μ of 8 for the first valve, we may expect an over-all magnification of 10 to 12, so that we may put the input to second valve at 10. This is again multiplied by the μ of the second valve, but is then stepped down to the crystal. With a μ of 8, and step-down of $1\frac{1}{2}$ to 1, we may expect to get 40 on the crystal. Of this we should get 20 to 30, say 15 on the transformer primary, giving, at 1 to 8 ratio, 200 on the first grid, for telegraphy (for telephony see below). If the second transformer has a 1 to 4 ratio, we have $200 \times 8 \times 4$ or 6 400 units on the second grid. So that in each case the L.F. grid input is so far above the H.F. on the corresponding grid that the latter can be neglected.

In telephony, we must remember that the L.F. is only a modulation on the H.F., so that the L.F. voltages will be smaller. If the modulation is 20 per cent., we can divide them by 5, still leaving the L.F. much larger than the H.F. This excess of L.F. over H.F. will increase with the number of valves used for H.F. If only one is in use, it will be found that the H.F. input may have to be considered in arranging the bias.

Apart from this point, the L.F. side should be dealt with just as an ordinary L.F. amplifier. If, however, as is usual, loud-speaker strength is being used, it will be necessary to have a power valve in the last stage. Now power valves as a rule are not suited for H.F. work, and it is a good rule to specify, for loud-speaker work, that the last shall be a pure L.F. power stage.

One additional point is that, owing to stray couplings, it will probably be found that the L.F. side works much better with the transformers connected in one particular way, so trials should be made with the windings reversed (not primary to secondary, but crossing and uncrossing first the primary and then the secondary leads).

General Notes on Sets of this Type.

As has been already stated, this type of set is not really suited to the self-heterodyne reception of C.W. We have used it mainly on telephony and ship work, and with a separate oscillator for long-wave C.W.

For broadcasting, it will be found that a two-valve set, with only the first valve reflexed, and the second a power valve, is perfection for the nearest B.B.C. station. Up to 40 miles or so it will give really good loud-speaker strength with moderate reaction, and up to 10 miles it works well on a small

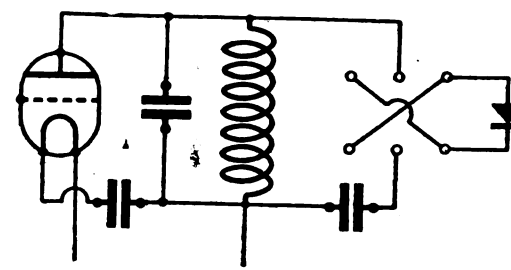

Fig. 2.

inside aerial. Increased by one reflex valve (*i.e.*, a 2-valve reflex plus one power stage) all the B.B.C. stations come in well on the loud-speaker. Long-wave stations up to, say, 3 000, come in equally well, but really need, for the highest efficiency, slightly larger by-pass condensers. This need shows more strongly on separate heterodyne long-wave work up to 20 000 metres, when larger condensers—say .001 in the grid circuits and .005 in the anode, become really necessary.

It will be found at first that the circuit has little tricks of its own when working at its utmost power, but these are soon learned, and it will then be found delightful to handle.

In our next instalment it is proposed to describe some of the alternative arrangements that have been suggested.

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The Propagation of Electric Waves through Liquids.

By S. G. Matthews. [R110

THE conduction of an electric current through a liquid, as in the case of a secondary cell, is a very different proposition from the conduction of a similar current in a metallic wire.

In the wire we have a number of free electrons which pass between the places occupied by the fixed atoms of the metal when a potential is applied. In a solution, such as the sulphuric acid of the secondary cell, there are no fixed atoms—which is the reason why the liquid flows—and it is also believed that there are no great number of free electrons. It does, however, contain a very great quantity of ions, *i.e.*, atoms or groups of atoms which have lost or gained an electron or electrons, thereby acquiring a charge of electricity.

Now, in the case of sulphuric acid, there are believed to be many millions of ions of two different kinds. The first of these is the hydrogen ion, which is a hydrogen atom that has gained an electron and become negatively charged; while the second is the sulphate ion, which is a group of four atoms, one of sulphur and three of oxygen, which has lost one electron and is therefore positively charged.

Now it is these ions which carry the current through the solution, the process being as follows: An electron enters the solution at one of the terminals and finds nearby a single hydrogen atom possessing, as usual, a single electron. The new electron joins up with the hydrogen atom, which then has two electrons and becomes a hydrogen ion. By virtue of its negative charge it is attracted to the positive plate of the cell and it passes across the solution to it, gives up its spare electron and becomes once again an ordinary hydrogen atom. This process is what occurs when a secondary cell is charged (with the exception of the chemical changes which take place on the surface of the lead plates), and is known as electrolytic conduction.

Now in the case of the passage of electric waves or of rapidly alternating electric currents through a solution, there has always been considerable doubt as to whether it was necessary for the ions to move right across the solution carrying the same electron to the other electrode or whether the electrons were exchanged during the passage. It could also be assumed that all the ions simply swing backward and forward under the impulse of the oscillating current and never move very far from their medial positions.

These problems reduce themselves, however, to the question: Do the ions move far or only a short distance as the waves of current pass through the solution? Until quite recently experiments indicated that the ions moved a relatively long distance. For example, it was found that the resistance of a solution was much higher at high frequencies than for D.C., or at frequencies of the order of 50 cycles per second, which indicated a relatively long path for the ions. It was thought that when the frequency was too high, it became impossible for the ions to complete their swing across the solution in one cycle of the wave.

Some experiments have been conducted recently in France however by M. Granier which have cast a doubt on this conclusion. M. Granier made every effort to remove sources of error, such as those due to capacity between conductors, electrodes, etc., with the result that the conclusion of a lower conductivity for very high frequency currents is wrong. When the disturbing effects of internal capacities in the apparatus have been removed or compensated, the conductivity of a given solution for high frequency current is practically the same as for low frequency current or, neglecting chemical effects, for direct current.

We can only conclude, therefore, that the conduction of electric waves in liquids is carried on by a process similar to that involved when a metallic conducting medium is employed: that is by the to and fro swing of charged particles, each ion, or electron if the solution contains free electrons, swings through only a small distance depending on the frequency of the current or wave that is passing through the solution.

In conclusion, therefore, we may say that no special electrolytic effects are to be expected due to the passage of wireless waves passing through or over the surface of the sea, which will behave exactly as does a metallic conductor having practically the same conductivity as sea water.

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The Paris Conference. [R545·06

REPORT OF SUB-COMMITTEE ON THE ORGANISATION OF THE INTERNATIONAL AMATEUR RADIO UNION.

THE Sub-Committee No. 1 of the Amateur Congress, on the organisation of the International Amateur Radio Union, convened at the Faculté des Sciences in Paris at 5 p.m. on the 15th April, 1925.

The following nations were determined to be represented by the delegates appearing after their respective names :—

ARGENTINA, AUSTRIA, BELGIUM' BRAZIL, CANADA, CZECHO-SLOVAKIA' DENMARK, ENGLAND, FRANCE, FINLAND' GERMANY, HUNGARY, ITALY, JAPAN' LUXEMBOURG, NETHERLANDS, NEW-FOUNDLAND, POLAND, SPAIN, SWEDEN, SWITZERLAND, URUGUAY, UNITED STATES.

By acclamation Mr. H. P. Maxim was elected Chairman of the Sub-Committee, and Mr. J. G. Hezger, Secretary.

The meeting heard a general and open discussion by many delegates as to form that the proposed Union should take, what its aims should be, etc., and adjourned at 7 p.m. after agreeing that the delegates should give the matter careful thought over the night.

Reconvening at 10.30 a.m. on the 16th April in the same hall, the meeting continued its consideration of the general nature that the proposed Union should assume. It was unanimously agreed by the representatives of twenty-one countries (all listed above except Luxembourg, absent) that there was a need for such a Union, that it should be an organisation by individual membership, that it should have for its chief purposes the co-ordination and fostering of international amateur two-way communication, and that the headquarters of such a Union should temporarily be located in America.

The A.R.R.L. delegate from the United States was requested to prepare a proposed Constitution along the lines agreed upon, for the consideration of the Sub-Committee. The meeting adjourned at 11.30 a.m. to reassemble at 9.30 p.m.

The Sub-Committee met again in the same hall at 10 p.m., 16th April, to consider the proposed Constitution, but, because sufficient copies thereof were not available, adjourned until 17th April.

The Sub-Committee met again in the same hall at 10 a.m., 17th April, each delegate being supplied with copies of the Constitution under consideration. The roll was called and it was found that delegates were present from the following countries: Argentina, Austria, Belgium, Brazil, Canada, Denmark, England, France, Finland, Germany, Italy, Japan, Netherlands, Newfoundland, Poland, Switzerland, Spain, Uruguay, and the United States, a total of nineteen countries.

The proposed Constitution was considered section by section, and each section adopted unanimously after mature debate. It was then voted upon as a whole, and was unanimously approved and adopted by the delegates of the nineteen countries represented.

A copy of the Constitution is attached hereto as a part of this report.

The Committee adjourned at 1 p.m.

(Signed) HIRAM PERCY MAXIM, *Chairman.*
HEZGER, *Secretary.*

Constitution of the International Amateur Radio Union.

(*Adopted 17th April, 1925.*)

ARTICLE I.—NAME AND OBJECTS.

1. The name of this organisation is the International Amateur Radio Union, hereinafter called the Union.

2. Its objects shall be the promotion and co-ordination of two-way radio communication between the amateurs of the various countries of the world; the advancement of the radio art; the representation of two-way amateur communication interests in international communication conferences; the encouragement of international fraternalism; and the promotion of such additional activities as may be allied thereto.

ARTICLE II.—MEMBERSHIP.

1. Any person interested in the objects of the Union shall be eligible to membership. Applications for membership shall be submitted to the Executive Committee of the Union and a majority vote of the said Executive Committee shall elect to membership. The said Committee may refuse to elect to membership any person who, in their opinion, would be an undesirable member; *provided* that any person who is refused membership may have his case reviewed by the Board of Directors of the Union upon the recommendation of two or more members of the Executive Committee, and the Board of

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Directors may, in its discretion, reverse the action of the Executive Committee.

2. Members shall comply with the requirements of the Constitution and of such regulations of the Union as may be adopted from time to time.

3. A member may voluntarily terminate his membership by written communication to the International Secretary. If all his dues and other indebtedness to the Union have been paid, the resignation shall be accepted.

4. Upon the written request of twenty-five or more members that, for cause therein stated, a member of the Union be expelled, the Executive Committee shall consider the matter, and if there appears to be sufficient reason, shall advise the accused of the charges against him. The accused shall then have the right to present a written defence, or to secure a hearing before a meeting of the Executive Committee, or authorised representatives of the Executive Committee, of which meeting he shall receive notice at least sixty days in advance. Not later than sixty days thereafter, the Executive Committee shall finally consider the case, and if in opinion of two-thirds of the members of the Committee a satisfactory proof of the undesirability of the accused as a member has been established, and he has not in the meantime tendered his resignation, he shall be expelled from membership.

Article III.—Sections.

1. In each country represented in the Union, from which there are twenty-five or more members of the Union, there shall be formed a Section of the Union, which shall be known as "..... Section, International Amateur Radio Union."

2. The members in any country not possessing a total membership in the Union of at least twenty-five, shall temporarily be attached for administrative purposes to a neighbouring country which shall be specified by the Executive Committee. Whenever the total membership from such a country attains a total of twenty-five or more, a Section shall be created in that country as provided in Paragraph 1 of this article.

3. In each Section of the Union there shall be a National President, elected by popular vote of the members in that country. Nominations for this office shall be solicited by the International Secretary through the columns of the official organ of the Union, under regulations as to eligibility, dates, etc., to be determined by the Executive Committee. The election shall be by means of ballots mailed from the headquarters of the Union.

4. The National Presidents shall hold office for a term of two years, or until their respective successors have been duly elected.

5. Whenever a vacancy occurs in the office of National President, an election for his successor shall be held as quickly as possible, under the same general regulations as apply for regular elections.

Article IV.—Officers.

1. The officers of the Union shall be an International President, an International Vice-President, and an International Secretary-Treasurer.

2. The first officers of the Union shall be elected by the amateur delegates present at the International Amateur Congress held in Paris, 1925, one vote to be assigned to each country represented. They shall assume office immediately upon election and shall hold office for two years or until their successors are duly elected.

3. Except for this first election of officers, the officers shall be nominated and elected by the Board of Directors for two-year terms, under regulations as to eligibility, dates, etc., that shall be determined by the Board.

Article V.—Management.

1. The affairs of the Union shall be managed under this Constitution by an Executive Committee, consisting of the officers of the Union and two Councillors-at-large.

2. The first Councillors-at-large shall be elected by the amateur delegates present at the International Amateur Congress held in Paris in April, 1925, one vote to be assigned to each country represented. They shall assume office immediately upon election, and shall hold office for a term of two years or until their successors are duly elected. Their successors shall be nominated and elected for two-year terms by the Board of Directors, under regulations as to eligibility, dates, etc., that shall be determined by the Board.

3. Whenever there is any vacancy in any office in the Executive Committee, it shall be filled by special election by the Board of Directors, under such regulations as they may determine.

4. The Executive Committee shall direct the investment and care of the funds of the Union, shall make appropriations for specific purposes, shall act upon all questions of admittance or expulsion of members, and in general shall direct the business of the Union, either itself or through its officers and Committees. It shall arrange the place, time and programme for the biannual Congress and shall handle all affairs relating thereto, either itself or through appointees.

5. It shall be the particular purpose and duty of the Executive Committee to devise ways and means for the encouragement of international two-way amateur radio communication: by the promulgation of rules and regulations to co-ordinate international amateur operation, by the management of tests and relays, by encouraging and assisting the development of amateur radio in countries where assistance is desirable, by arranging for adequate representation of two-way amateur communication interests at international communication conferences, by endeavouring to secure a removal of legal restrictions prohibiting amateur operation in certain countries, and by kindred methods.

6. The Executive Committee shall meet in person at the call of the International President when possible and desirable. At such meetings three members of the Committee, present in person or by proxy, shall constitute a quorum, and action shall be determined by the concurring vote of a majority of the members present. In general, however, the determinations of the Executive Committee shall be made by post, through the Agency of the International Secretary-Treasurer and under the direction of the International President, and action shall be determined by the concurring vote of a majority of the whole membership of the Committee. The International Secretary-Treasurer shall acquaint the entire membership of the Board of Directors with the actions taken by the Executive Committee, and such actions shall then become binding upon the Union; *provided* that if three or more National

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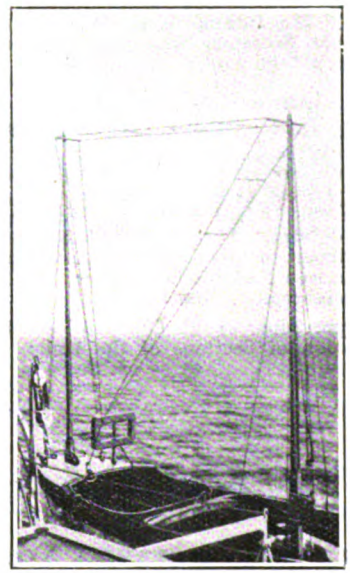
Presidents within sixty days after such announcement of action by the Executive Committee formally protest the same, the Executive Committee shall cause the International Secretary-Treasurer to submit the question in point to the entire Board of Directors by post, and unless it is within one hundred and twenty days thereafter ratified by a majority of the Board of Directors, the action of the Executive Committee shall be deemed reversed.

7. The International President shall have general supervision of the affairs of the Union, under the direction of the Executive Committee. He shall preside at meetings of the Executive Committee and at the Congresses, and shall direct the work of the International Secretary-Treasurer in the determination of Executive Committee affairs by post. He shall be, *ex-officio*, a member of all committees. The International Vice-President shall be responsible for such matters of general supervision as may be delegated to him by the International President. In the absence or disability of the International President the International Vice-President shall act in his stead.

8. The International Secretary-Treasurer shall be the general manager of the affairs of the Union, under the direction of the International President and the Executive Committee. He shall attend all meetings of the Executive Committee and all Congresses and record the proceedings thereof. He shall collect all moneys due the Union and deposit them in the name of the Union in a depository satisfactory to the Executive Committee. He shall certify the accuracy of bills or vouchers on which money is to be paid, and shall draw and sign all cheques. He shall invest such funds as may be ordered by the Executive Committee. He shall have charge of the books and accounts of the Union and shall furnish to the Executive Committee from time to time such statements and reports as may be required. He shall conduct the general correspondence of the Union, and shall keep full records. Under the direction of the International President he shall canvass the Executive Committee by post to determine the action of the Union on current matters. He shall be in responsible charge, under the International President and the Executive Committee, of all property of the Union. He shall, with the approval of the Executive Committee, employ such clerical force as may be necessary and shall be responsible for the work of all employees of the Union. Under the direction of the Executive Committee, he shall be the general manager of any publications owned by the Union. He shall prepare and submit at each Congress of the Union a comprehensive report on the progress and status of the affairs of the Union. He shall perform such other duties as may be assigned to him by the Executive Committee. He shall furnish a bond satisfactory to the Committee, the expense of same to be borne by the Union.

9. The National Presidents shall have general supervision of the activities of the Union in their respective countries. They shall be responsible for carrying out in their respective countries the plans and policies of the Union. They shall represent their respective countries on the Board of Directors, and to this end shall keep themselves informed on the needs and desires of their members, in order that they may faithfully and intelligently represent them. They shall have the right to appoint such assistants as they deem desirable, to handle such portions of their duties as they desire. So far as possible, they shall attend all Congresses of the Union, but shall be authorised to send an alternate of their own selection to act in their stead at the Congresses.

10. No person commercially identified with the radio industry shall be eligible to serve as a member of the Executive Committee or as a National President. All members of the Executive Committee and all National Presidents must be members of the Union.



Showing the aerial system of the Marconi transmitter now being fitted to lifeboats. Note the D.F. frame aerial.

ARTICLE VI.—BOARD OF DIRECTORS.

1. The officers of the Union, the Councillors-at-large, and the National Presidents of Sections of the Union together shall constitute the Board of Directors.

2. The Board of Directors shall meet in biannual Congress in April of each odd-numbered year, at the call of the Executive Committee. The Executive Committee shall select the exact dates and the place, shall plan and announce the programme, examine and authenticate credentials, and in general administrate the Congress.

3. At the Congress, the Board of Directors shall receive the reports of the officers, elect and instruct the new officers and Councillors-at-large; act upon such matters as may come before it; and in general delineate the policy of the Union for the ensuing two years. The rules of order of the Congresses shall be so arranged as to permit free and open discussion of international amateur radio matters.

4. Members of the Board of Directors present in person or by alternate or by proxy to a number

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representing one-third of the membership of the Board, shall constitute a quorum at any Congress. The actions of the Congress shall be determined by the concurring majority of those present, but if less than a majority of the whole membership of the Board is present the actions taken shall not become binding upon the Union until they have subsequently been ratified by a majority of the whole membership of the Board.

5. If the finances of the Union, in the opinion of the Executive Committee, permit it, the travelling expenses of the International President and the International Secretary-Treasurer to attend the Congresses shall be paid by the Union.

ARTICLE VII.—A.R.R.L.

1. Until otherwise determined by the Board of Directors by the amendment of this Constitution, the headquarters of the Union shall be located at the headquarters of the American Radio Relay League in the United States of America. Until otherwise determined by the Board of Directors by the amendment of this Constitution, the magazine of the American Radio Relay League, *Q.S.T.*, shall be the official organ of the Union.

2. The provisions of this Constitution relating to the formation of Sections of the Union and the election of National Presidents shall not apply in the United States and Canada. The United States portion of the A.R.R.L. shall constitute the United States Section of the Union and its President shall be deemed the National President of the Section within the meaning of this Constitution. The Canadian Section of the A.R.R.L. shall constitute the Canadian Section of the Union and the A.R.R.L. Canadian General Manager shall be deemed the National President of the Section within the meaning of this Constitution.

ARTICLE VIII.—DUES.

1. The dues for membership in the Union shall be one dollar ($1.00) per annum.

2. Members in arrears shall be carried on the records of the International Secretary-Treasurer for ninety days. If by the end of that time they have not renewed their membership, they shall be dropped from the rolls.

ARTICLE IX.—AMENDMENT.

1. This Constitution may be amended by a two-thirds vote of the Board of Directors, at any Congress. At the initiative of the Executive Committee it may be amended at any time by post by a two-thirds vote of the Board of Directors.

Accumulators for High Tension Supply.

[R621·354·009

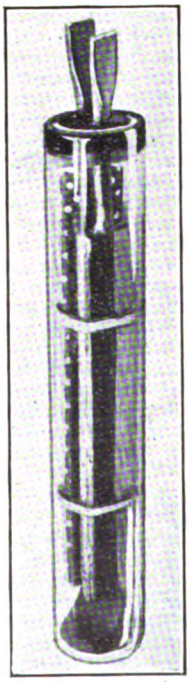
MESSRS. C. A. VANDERVELL & CO., LTD., Acton, London, W.3, have for some time been manufacturing small accumulator cells, a number of which are connected up in series for the plate supply of a valve set.

For any but the smallest sets, high tension accumulators of this type are almost a necessity. As everyone knows, the usual small-capacity, dry cell batteries, used with multi-valve or power amplification sets, are of very little use. The disadvantage of the accumulator cells, however, is heavy initial cost.

The C.A.V. H.T. accumulators are supplied fully charged, and are in two forms—with "jelly" electrolyte or dry charged. The first type is stated to be a vast improvement. The electrolyte is run into the cells in liquid form, and it sets in perfect contact with the plates. It is claimed that it may be left standing for 12 months, keeping the plates inert throughout this period. Another advantage is that the electrolyte is unspillable.

The other type (dry charged) is supplied with plates which have been subjected to a long process of forming. To prepare the cells for use it is only necessary to fill with acid of a specified density, when 75 to 90 per cent. of the full capacity will be obtained.

One of the most popular types of accumulator unit put up by Messrs. Vandervell is the "H.T.3." This consists of 30 cells, each of one ampere-hour capacity, connected in series to give 60 volts. Each cell contains two plates, which rest on celluloid prisms, with ribbed separation. The mouth of the cell is permanently sealed, and contains a special vent plug. The cells are connected by bending over the plate extension lugs and burning them together.



Means for making tappings are provided at every sixth cell.

The whole assembly is enclosed in a strong wooden case with a lid, and plugs and sockets for making connections are provided. The prices of this model are £3 dry charged and £3 10s. dry charged with jelly electrolyte.

We have had a set of these in use delivering 6 mA during broadcast hours for three months on one charge, and they have been very satisfactory.

Other model cells are made, having larger capacities, such as the H.T.2, and the H.T.1 with capacities of 2 and 3 actual ampere-hours respectively.

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Apparatus Tested. [R009

TWO R.I. COMPONENTS.

A NUMBER of components manufactured by Messrs. Radio Instruments, Ltd., of 12, Hyde Street, Oxford Street, W.C.1, have recently passed through our test room, and a description of the results obtained with two of them are given herewith.

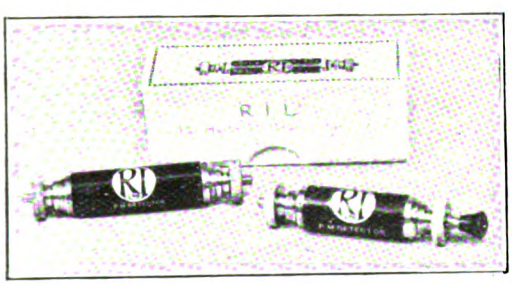
The "Permanent Mineral" Detector. [R374·009

The makers claim that this is a really permanent detector, not needing adjustment, and one pattern is therefore supplied in a "fixed" form. Realising, however, that most experimenters prefer facilities for improving the adjustment, another type is supplied, in which a spring plunger is provided, thus enabling correct adjustment to be made.

The detector is of the double crystal type, one of the crystals being apparently bornite and the other a special compound of zinc (not the usual zincite).

For our tests the adjustable type was used. The method of testing has been described before in these pages, and it will be remembered that we measure the H.F. input power and the D.C. output power, and express the latter as a percentage of the former, which gives us the "efficiency."

Five points were taken at random and tested at 0.5 volt, at which voltage the efficiency varied



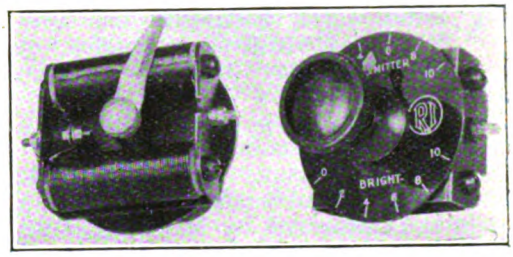
from 5.8 to 40 per cent., the H.F. resistance varying greatly also. Incidentally, in this case, the test of five consecutive points is hardly fair, since the double crystal type of detector is not expected to be sensitive all over, as are some of the treated galena crystals.

A really good setting was then obtained, and tests were performed at various voltages. It was found that for high voltages, corresponding to strong signals, the efficiency was 52 per cent., which is roughly that of a first-class galena. For lower voltages the efficiency dropped, which is usual with this type of detector.

One of the chief claims of the makers, however, is for stability, and this was tested by jolting the test apparatus and applying sudden high voltages to represent atmospherics. Nothing we could do (within reason) made the slightest difference to the results obtained, and therefore the detector can be accurately described as permanent; and as instability is often cited as a reason for not using a crystal as detector in a valve set, it is suggested that the R.I. detector may remove this difficulty—with a consequent improvement in the tone of reproduction. The price of either type of detector complete with mounting brackets is 6s. retail.

The "Duostat." [R383·3·009

This is a double rheostat, having two separate windings, with resistances of 4 and 25 ohms respectively, and is suitable for controlling the fila-



ment heat of both bright and dull-emitter valves. The resistances are of wire, wound on two cylinders mounted parallel to each other, and the contact is arranged so that a complete revolution of the knob gives a range of 0-4 ohms and 0-25 ohms. A definite "off" position is provided. The dial is engraved for the "dull-emitter" and "bright" ranges.

The rheostat is both mechanically and electrically sound, the movement of the slider being very sweet, and the variation of resistance quite regular. The price is 7s. 6d.

THE "DARCO" GRID-LEAK. [R383·1·009

We have recently had the opportunity of testing some Darco grid-leaks, which are being made by Messrs. Darco, Ltd., 77-79, High Street, Watford, and sold at 2s. each. The process of manufacture is novel, but we are not at liberty to disclose details at present. It is sufficient to say that there is

every prospect that the leaks will prove constant in use.

The makers are able to claim an accuracy of 15 per cent. for these accessories, which is, of course, very good: on test, however, we found they were even better. Of the six tested, only one approached an error of 15 per cent., the average of the batch being 7 per cent.

The component is tubular in form and of the usual size. It can be connected up by the nuts and screws provided, by soldered connections to the tags, or by the usual grid-leak clips.

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The Rectification of Small Radio Frequency Potential Differences. [R149

A paper read by Mr. F. M. COLEBROOK, B.Sc., D.I.C., A.C.G.I., before the Radio Society at the Institute of Electrical Engineers, on 27th May, 1925.

AN Ordinary Meeting was held at the Institute of Electrical Engineers, Victoria Embankment, London, on Wednesday, 27th May, Admiral Sir Henry Jackson in the Chair.

The minutes of the previous meeting were taken as read and confirmed.

The following paper was then read: "The Rectification of Small Radio Frequency Potential Differences," by Mr. F. M. Colebrook.

Mr. COLEBROOK said: About a year or so ago it became necessary in connection with some work at the National Physical Laboratory to have some quantitative information with regard to the phenomena of rectification. On going through the literature of the subject at that date, I found that very little work of a really useful practical kind had been done, and that if I wanted to find out anything about the subject I should have to find it out for myself, starting practically from scratch. I did so, and I have not in any way regretted the necessity that was laid upon me at that time, because it proved to be an exceedingly useful and interesting subject. I hope I shall be able to-night to make it at least as interesting for you as it was for myself. I have got the results of nearly a year's work to cover in a very short time, and I shall probably make considerable demands upon your attention.

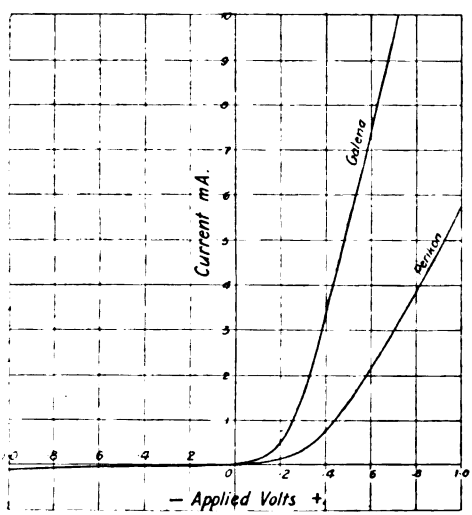

Fig. 1.

With regard to the scope of the present talk, it is going to be concerned with the general principles of rectification, with special reference to crystal detectors. I have continued the work with valves, and a paper on that subject will probably be published some time in the future in EXPERIMENTAL WIRELESS & THE WIRELESS ENGINEER, but I am afraid I shall not have time to go into the valve side of the question to-night. Further, I am going to deal with the subject from the electrical and not from the physical or molecular-physical point of view. I am not going to consider at all the internal molecular mechanism of rectification, but shall consider a rectifier as a conductor of electricity having certain special useful properties.

I am going to approach the subject by very easy stages. Of course, the most common application of the crystal detector at the present day is to the reception of telephony or broadcasting, but when you have a crystal detector connected across a coil and in series with an inductive load you have a mass of complexity which it would be very difficult to resolve into simple terms. Therefore, in order to get an understanding of what happens in the practical application, it is necessary to approach the subject from the very beginning on the simplest possible lines.

I do not think I need go very deeply into the essential and fundamental principles of rectification, but it will be well to have some understanding of what we mean by it, and for the purposes of this lecture I propose to define it on these lines; we will consider a rectifier to be a conductor of electricity whose current-voltage relationship can be expressed in the perfectly general form: $i=f(e)$.

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That looks very mathematical, but it only means that i depends upon e; but it depends upon e in some way which is different

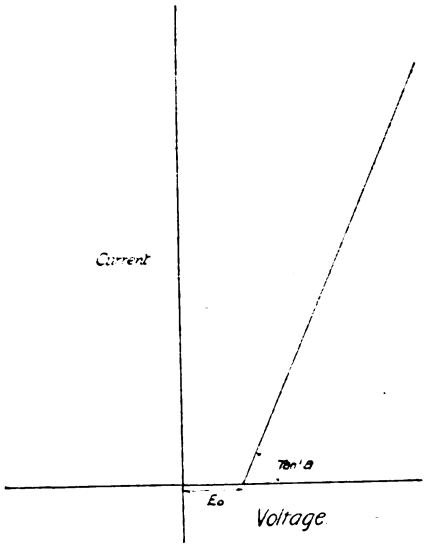

Fig. 2.

from the ordinary Ohm's Law relationship which applies to the ordinary conductor of electricity.

Rectification is used for the purpose of obtaining continuous current, or a continuous voltage, from an alternating electromotive force. If, therefore, the e in this case is an alternating E.M.F., the characteristic of a detector will turn that sine wave alternating E.M.F. into a current whose shape is not a sine wave, but some irregular form such that its mean value is finite. If $e = E \sin \omega t$ is the alternating E.M.F., the mean value of the current during one period is given by the formula :—

$$I_c = \frac{1}{T}\int_0^T f(e)\,dt.$$

The most common form of conductor which has this characteristic is the ordinary crystal detector. The current-voltage characteristic of the crystal detector is, in most cases, a curve of the type shown in Fig. 1.

When I started work on this subject, I thought it would simplify matters very much if I could find some simple expression for that characteristic, and I spent several months trying all possible kinds of functions to represent it in symbols in such a way that the necessary calculations of efficiencies, etc., could be carried out. I had to give it up, but I was able to establish quite a satisfactory compromise. For large amplitudes, this characteristic is very much like Fig. 2; *i.e.*, for amplitudes greater than .4 or .5 volt we can consider the crystal detector behaves as if its current-voltage characteristic were of this comparatively simple form, which is a form on which calculations can be based. That, of course, applies only to comparatively large signal amplitudes, greater than .4 volt. For amplitudes smaller than that, say up to .1 volt, a suitable enlargement of Fig. 1 will give a curve something like Fig. 3.

This second type of curve is a perfectly smooth continuous curve, and can in general be represented by a fourth power equation. That, again, is perfectly amenable to mathematical treatment. As far as the galena detector is concerned—which is the most commonly used crystal detector at the present time — Fig. 2 can be represented by the equation :—

$$i = a\,(e - e_0).$$

where e_0 is the small potential difference, so marked in Fig. 2, and a is the slope of the

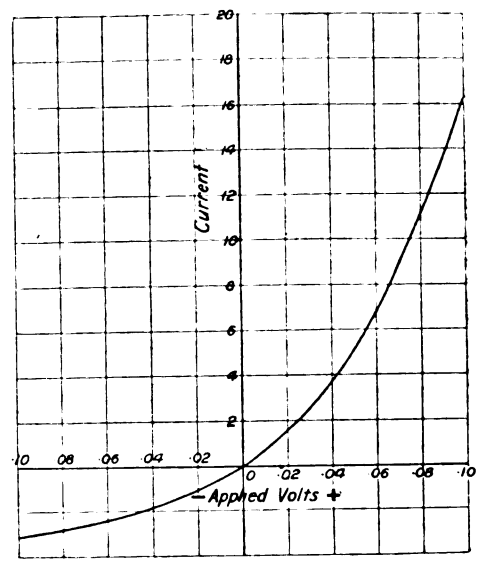

Fig. 3.

line. e_0 is generally about .25 volt, whereas the co-efficient a is usually of the order of about 3×10^{-2}, or 3/100. These two forms of

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characteristic, from which calculations can be made comparatively simply, are exceedingly useful for any investigation of the behaviour of detectors.

Now I come down to the more practical view of the situation. In most applications of the crystal detector there is some form of load in series with the rectifier, because the rectifier is used in order to make readable certain radio-frequency signals. When a load is included in series with the rectifier, the whole of the conditions of operation are fundamentally altered, and any discussion as to efficiency or values of resistance, etc., must be based on a consideration of a loaded rectifier circuit. The first kind of circuit I am going to talk about can be represented in general form, as in Fig. 4.

That, I think, is the simplest form of circuit in which we have a crystal detector supplying a continuous current to a load. The load, for the sake of simplicity, I have shown in the form of a non-inductive resistance. The E.M.F. will be taken to be

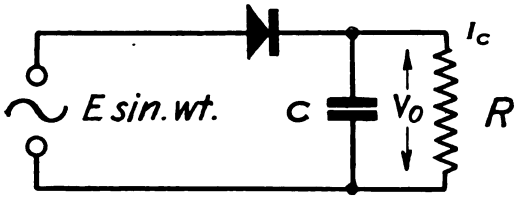

Fig. 4.

a pure sine wave alternating E.M.F., and it is to be considered as a *maintained* E.M.F. Whatever the load imposed upon that source of E.M.F., the E.M.F. is maintained: that is an important difference between this ideal simple application of the crystal detector and the reception of wireless telegraph signals, but we have to take the simple case first and see what we may expect when we come to the more complicated case.

The load is short-circuited by a condenser. That, of course, is very general practice, and I have found that it is a fundamentally sound practice. That condenser is to be considered as of sufficient magnitude to prevent any appreciable fall of high-frequency voltage in the load due to the passage of the high frequency components of the current flowing in the detector circuit. In virtue of the characteristic of a detector, there will flow in this circuit a certain small rectified continuous current, for which I will use the symbol I_c. Here we can fall back on Ohm's Law. We have a current flowing and a resistance in the circuit. It therefore follows that somewhere in the circuit there is a continuous E.M.F. It is also common knowledge that if that resistance is removed, the continuous current flowing in this circuit will not rise to any phenomenally large value. That means that even if there is no external resistance in the circuit there is still a resistance somewhere in the circuit which limits the current. We have, therefore, in a rectifier circuit a continuous E.M.F. associated with some form of permanent resistance which we may consider as an internal resistance. We must therefore necessarily have, as an expression for the current in the load, an equation of the simple form :—

$$I_c = \frac{E_c}{R_c + R}.$$

I have used E_c to represent the effective rectified E.M.F., and R_c to represent the internal resistance. Both of these quantities must be associated with the crystal, since there is no other place they can be associated with. Both of these are clearly the important quantities that we want to know something about in relation to the crystal detector. Of course, they are not constants but will vary considerably, not only with the amplitude of the high frequency signal E.M.F., but also with the magnitude of the load R. I should like to make it clear that these two quantities, E_c and R_c are not merely mathematical fictions and convenient expressions, but that they do actually correspond to physical realities in this process, and I shall have to presume on your good nature while I write the details down in mathematical form. It is not a very abstruse form of presentation, but it will need a lot of talking unless I do it in this way :—

If $i = f(e)$, $e = E \sin \omega t$, and if there is no load in the circuit, the expression for the rectified current is :—

$$I_c = \frac{1}{T}\int_0^T f(e).dt = F(E).$$

If there is a load in the circuit, then the voltage operating on the detector instead of being e will take this form : $e - v_0$ where v_0 is the back E.M.F. due to the passage of the continuous component of the

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current through the resistance load. The continuous component in this case will be the mean value of $i = f(e - v_0)$ over a period,

$$I_c = \int_0^T f(e - v_0)dt.$$

It can be expressed in the form of an infinite series of terms involving successive powers of this continuous back E.M.F.:

$$I_c = F(E) - v_0 F_1(E) + \frac{v_0^2}{2} F_2(E) \ ..$$

It can be shown that

$$E = \frac{F(E) + \frac{v_0^2}{2!} F_2(E) + \ ..}{F_1(E) + \frac{v_0^2}{3!} F_3(E) + \ ..}$$

$$\frac{1}{R_c} = F_1(E) + \frac{v_0^3}{3!} F_3(E) + \ ..$$

These functions of the amplitude are comparatively simple functions derivable from the known form of the static characteristic of the detector. It is clear from the form of these functions that if there is no load in the circuit there is still an effective internal resistance. We can show the effect of having no load in the circuit by removing that part of the expression involving v_0.. We are left with the simple expression $1/R_c = F_1(E)$. That function is the mean value of the first differential of the static characteristic, *i.e.*, it is not a thing which can be estimated by simply looking at the characteristic. It is a mean value function. The E.M.F. at no load can be obtained in the same manner. It is $\frac{F(E)}{F_1(E)}$. Dividing E_c by R_c at no load we are left with our original expression for the continuous component in the rectified current. That shows that these quantities, the effective rectified E.M.F. and the effective internal resistance, are actual physical realities and are important characteristics of a detector. I will give you some illustration of their importance by means of Fig. 5.

Suppose we have this simple rectifying circuit which I have been speaking about, and we apply a certain measured E.M.F., then we can plot the rectified current against the amplitude of the applied alternating E.M.F. and we shall get a curve like that marked "galena, no load." The same curve plotted for a perikon detector would come very much lower down the diagram. This would lead you to imagine that perikon is a very much less sensitive detector than galena, but now see what happens when you put a load of

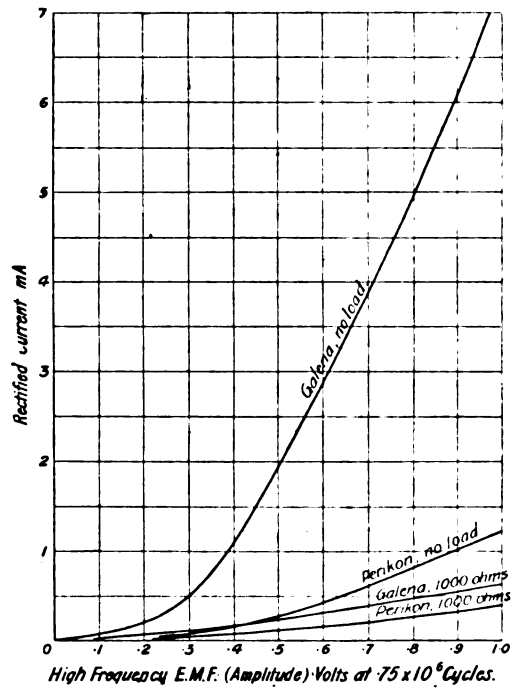

Fig. 5.

about 1 000 ohms in series with each of them. Although the galena detector is still somewhat more sensitive than the perikon it is not quite twice as sensitive, whereas judging from the first, or no load curves, you would think that galena was at least five or six times as sensitive as the perikon detector. The reason for this is perfectly clear in terms of the rectified E.M.F. and the effective internal resistance. It means that in these two cases the rectified E.M.F. is, perhaps, slightly greater in the case of galena than in the case of perikon, but the effective internal resistance is very much higher with perikon than it is for galena, and the result is that at no load a much greater rectified current flows in the galena circuit. When, however, the detector is called upon to do some work, the apparent superiority is greatly reduced, because the real merit of the detector depends chiefly upon the magnitude of its rectified

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E.M.F.; and although it is slightly greater in the case of galena than in the case of perikon, the superiority is not nearly so great as the no load characteristics would

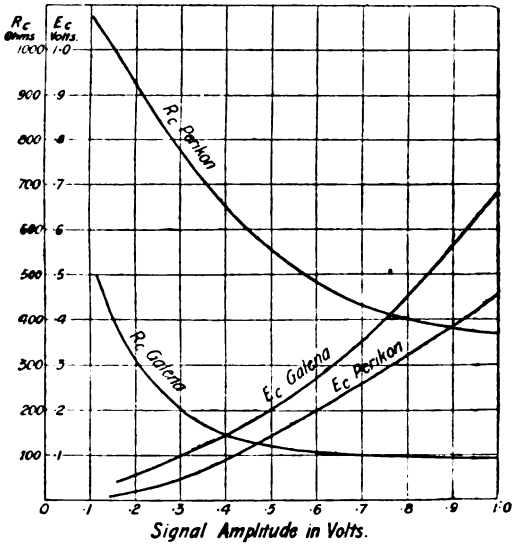

Fig. 6.

lead you to imagine. It may be of interest to show one or two curves indicating the values of these important quantities in the case of the typical detectors. (Fig. 6.)

These curves show the values of the rectified E.M.F. and the effective internal resistance at no load, *i.e.*, the limiting values assumed by these quantities when R is zero. You will see that when the rectified E.M.F. is, for large amplitudes, something like half the signal amplitude, the effective internal resistance varies enormously with the signal amplitude. For comparatively large amplitudes it is relatively small. When the signal amplitude is about one volt, the effective internal resistance is only about 100 ohms for galena, but when you come down to .05 volt, the effective internal resistance goes up to 5 000 ohms, and that is characteristic of both the more general types of detector, the galena and the perikon.

One interesting deduction from the equations above is that there will be a rectified E.M.F. operating in the output circuit even if the load is made infinite, so that there is no continuous current flowing at all. You can see how that arises in this way. The back E.M.F. across the load is given by this expression: $v_o = Ri_c = \frac{RE_c}{R_c+R}$. Now, the limiting value of this fraction, $R/(R_c+R)$, when R is made infinite, is clearly 1, so that we have the limit of v_0 when R is infinite, as E_c. In other words, if there is no path for the continuous current to flow in at all, there will still be a rectified E.M.F. The form of the functional expression for this rectified E.M.F. indicates that it will increase with the load resistance in series with the detector. The last slide showed you that the magnitude of the no-load rectified E.M.F. for a galena detector was about half the signal amplitude. If we increase the load to infinity and then measure the rectified E.M.F., we should find that it is considerably greater than half the signal amplitude. I measured the effective rectified E.M.F., corresponding to infinite loading, for various specimens of both types of detector, the method being as shown in Fig. 7.

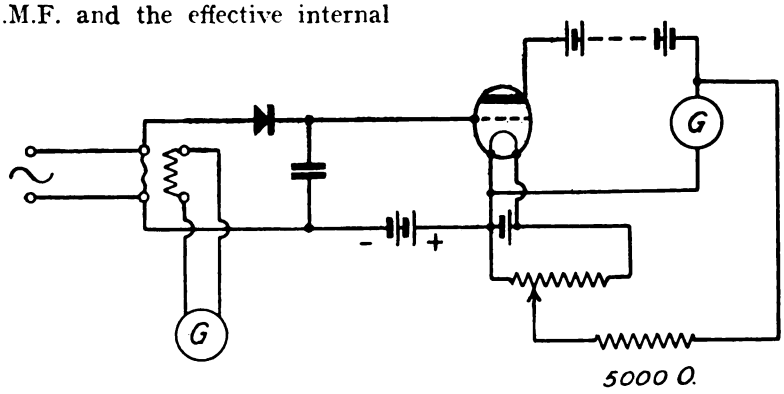

Fig. 7.

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A detector in series with a source of high frequency E.M.F. was connected directly to the grid of a valve, and a sufficient negative potential was applied to the grid through the crystal to ensure that there would be no grid current flowing in the grid filament circuit. This, therefore, apart from the secondary effects of any inter-electrode capacities, can be considered as a path of infinite resistance, and there will be no continuous current flowing in the rectifier circuit. In the anode circuit of the valve is a sensitive reflecting galvanometer. If there is a change of potential on this condenser—in other words, if the rectified E.M.F., E_c, actually exists under the conditions of infinite load, there will be a change of potential which will be indicated by a change in the current flowing in the anode circuit, and this can be read on the galvanometer. Its magnitude in terms of change of grid potential can be determined by an ordinary D.C. calibration. I measured the change of E_c corresponding to infinite load for the two principal types of crystal detectors, and the results are shown in Fig 8.

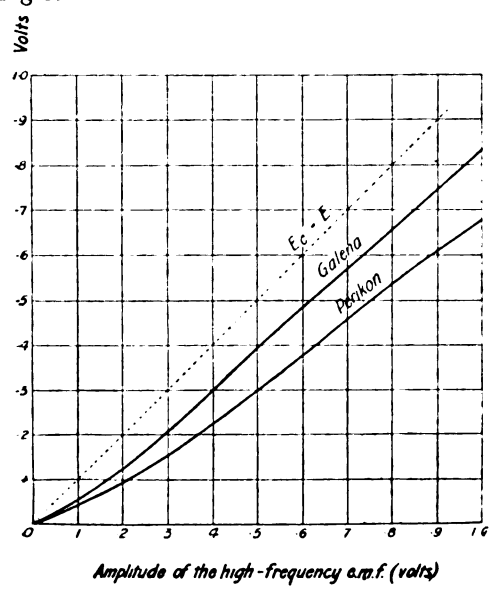

Fig. 8.

You will see that, as I said just now, the rectified E.M.F., corresponding to infinite load, is considerably greater than the rectified E.M.F. corresponding to no load, and the extraordinary thing about the curves is the apparently very high efficiency of crystal detectors as rectifiers of potential purely and simply. In the case of the galena detector particularly, the change of potential across the detector reaches something like 70 or

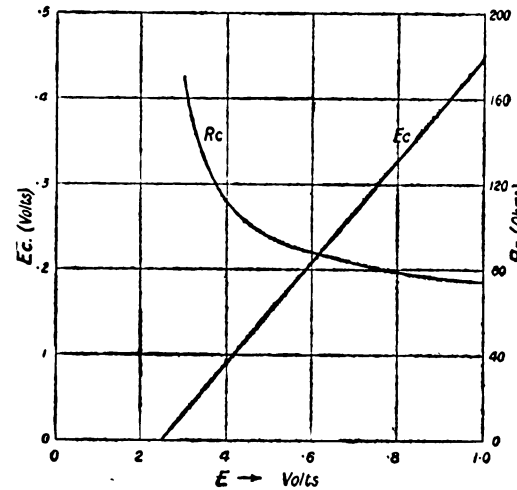

Fig. 9.

80 per cent. of the signal amplitude, *i.e.*, the change of grid potential is greater than the root mean square signal voltage and is nearly equal to the actual signal amplitude. In the case of the perikon detector the E_c is not quite so large, but even so the detector appears to be very efficient as a rectifier of potential. If the simple form of characteristic indicated in Fig. 2 applies, the open circuit rectified E.M.F. should be of magnitude E, the signal amplitude, minus e_0. For the galena detector recorded in this Figure, e_0 is between .15 and .2 volt. We should expect therefore that if this characteristic represented the behaviour of that galena detector, the open circuit rectified E.M.F. would be about .8 volt when the signal amplitude was 1 volt, and you see from the curve that it does approximate to that figure. That indicates that this type of characteristic will approximately represent the behaviour of these detectors at large amplitudes.

Fig. 9 indicates the calculated variation of E_c and R_c with signal amplitude with the ideal straight-line characteristic. Of course, if the signal amplitude does not exceed the small E.M.F. e_0, there will be no rectification taking place at all, and therefore the curve showing the variation of E_c and E will cut the axis at a point corresponding

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to a potential equal to e_0. These curves are calculated for a value of .25 for e_0, and correspond roughly with an ordinary galena detector, and you see the curve cuts the axis for a signal amplitude of .25. The R_c values show the same kind of variation as the other curves, *i.e.*, the R_c comes down fairly low for large signal amplitudes but at small signal amplitudes it begins to rise to a very high value. It cannot rise so high in this ideal case as in the experimental one, because the function becomes discontinuous when the signal amplitude becomes less than e_0, but there is the tendency for the internal resistance to rise to a very high value for small signal amplitudes.

Fig. 10 shows how the quantities E_c and R_c vary with the load. This is not for the ideal straight-line characteristic, but for the characteristic which corresponds to the operation of the detector at small amplitudes, *i.e.*, the fourth power characteristic. In the case of E_c, which increases slightly with the load, the values of the resistance of the load are marked on the top scale. The bottom scale shows back E.M.F. You see that with a load of 110 000 ohms, E_c is increased by 30 per cent. R_c decreases slightly with load, but it is characteristic of both these types of detectors that the quantities E_c and R_c are much more constant under small amplitude conditions than under large amplitude conditions. Also, that E_c is a very much smaller fraction of the signal amplitude when the signal amplitude is small, whilst the internal resistance is very considerably greater when the signal amplitude is small.

Now I come to what is a very important feature of the effect of this back E.M.F. on

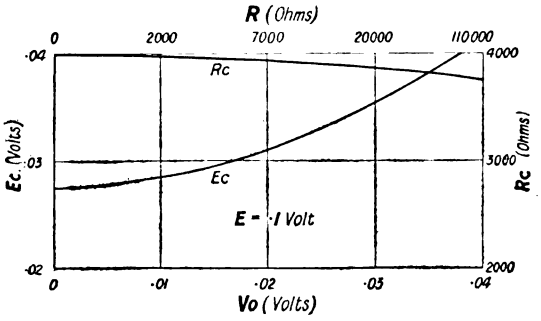

Fig. 10.

the operation of a detector. This has an important bearing on the use of a detector for the reception of radio-telegraphic signals. If we represent the static characteristic of a detector by a curve of the type of Fig. 11, then the effect of applying a continuous wave signal to the terminal of that detector can be represented as a variation of the potential in a simple harmonic manner on either side of the zero of the origin of the diagram. That is what happens when there is no load in series with the rectifier, and obviously the wave shape of the current will be a curve of the character shown, the mean value of that curve being, of course, the magnitude of the rectified current. But what happens when you put a load in series with the rectifier, that load being short-circuited by a condenser? There will be a back E.M.F. of the magnitude v_0 (Fig. 12), which is equal to the resistance multiplied by the magnitude of the continuous current. That back E.M.F. acts on the detector just as the alternating signal does, so that our new state of affairs is not a simple harmonic variation of potential about the point of origin. There is a shift back, so to speak, of the centre of the potential oscillation by an amount v_0, and our potential oscillation will now take place about the line A B, instead of the real origin of the diagram, and we shall have an oscillation of potential on either side of this new point of origin. The wave shape of the current will now be rather different, as there will be a much longer period of the alternation during which only a very small reverse current is flowing. It is obvious that the fundamental component of the wave form — which is, of course, the high frequency current of the same frequency as the supplying E.M.F.— will be very different in the second case from what it was in the first. The effect of that is that the same E.M.F. acting on the detector will produce a much smaller high frequency current in the second case than it did in the first. In other words, the apparent high frequency resistance of the detector is increased as the result of putting a continuous current load in series with the detector. It should be perfectly clear that the high frequency current does not flow through that load at all; nevertheless the effect of putting that resistance load in the rectifier circuit is very greatly to increase the high frequency resistance of the detector.

It is often said that if a detector has a characteristic of this kind, it is a good thing to apply a small polarising potential in order that the centre of oscillation shall occur at

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the point where the curvature is most marked. It may or may not be an advantage, it depends a great deal on the circuit conditions, but one thing is certain, and that is that in estimating by the appearance of the static characteristic the effect of applying a potential difference across the detector, you do not want to imagine that when you have applied that potential difference the oscillation will be taking place about the same point. Actually, it will be taking place about some point a long way farther back on the characteristic on account of this continuous fall of potential across the D.C. load which you have in series, and this back E.M.F. may reach considerable magnitude.

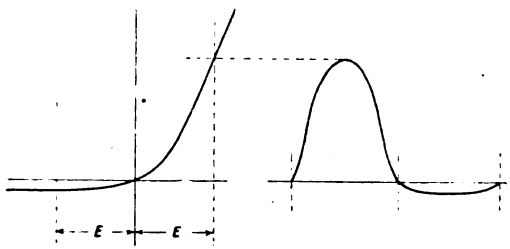

Fig. 11.

If you make R big enough, then you will get a back E.M.F. corresponding to the full rectified E.M.F. in the rectifier circuit, and this back E.M.F. may carry the centre of oscillation right back to very nearly the full amplitude of the signal. You saw that in the case I described where there was an infinite load in series with the detector. That back E.M.F., v_0, was equal to .8 of the signal amplitude, so that this shift of potential very considerably and profoundly modifies the behaviour of the rectifier. It may be that this is a considerable disadvantage; but it is not necessarily so, because the effect of this backward shift of the centre of oscillation is actually to increase very considerably the efficiency of the crystal as a transformer of alternating current energy into continuous current energy.

That is the side I must consider now, because that is, after all, the function of a crystal detector; it is to turn a radio frequency E.M.F. into continuous or low frequency current energy available for the operation of recording or detecting apparatus.

The fundamental equation describing the behaviour of a rectifier in series with a continuous current load is the one which we have had already, *i.e.*,

$$I_c = \frac{E_c}{R_c + R}.$$

In other words, it is as if we had a source of continual potential with a certain internal resistance. It is well known that you will get maximum D.C. power from a combination of that kind when your external load is equal to the internal resistance. Actually E_c depends on the load and increases with the load, while Rc decreases with the load, so that if you were to measure E_c and R_c on no load and then insert a resistance equal to R_c, you would not be developing your maxi-

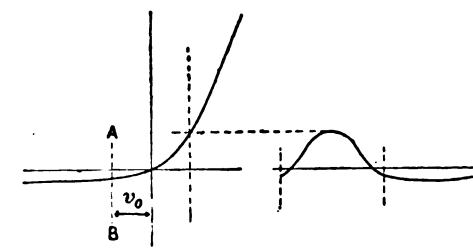

Fig. 12.

mum continuous current energy. But the value of the resistance which, in fact, gives maximum continuous current energy, is not very different from the value of R_c determined on no load. In the case of the ideal straight-line characteristic, with a signal amplitude of 1 volt, the resistance corresponding to maximum output would be about 98 ohms, whereas the internal resistance on no load is about 70 ohms; but you will see that the resistances are of comparable magnitude. For galena the optimum load would be about 100 ohms, whilst the figure for perikon would be from 400 to 600 ohms for a signal value of 1 volt. This, of course, is running right in the face of current practice, because no one would dream of putting a resistance so low as that in series with a crystal detector and expect to get maximum D.C. output. It must be remembered that these conditions correspond to a maintained E.M.F., but actually the E.M.F. is not maintained. It would be truer to say that the input condition is one of constant energy than one of constant input E.M.F., because there is a limit to the amount of energy which can be received by an aerial in cases of ordinary direct crystal reception.

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What is required, therefore, is not a condition which will give you the maximum value of the continuous current power; we want a condition which will give the highest efficiency of transformation of A.C.

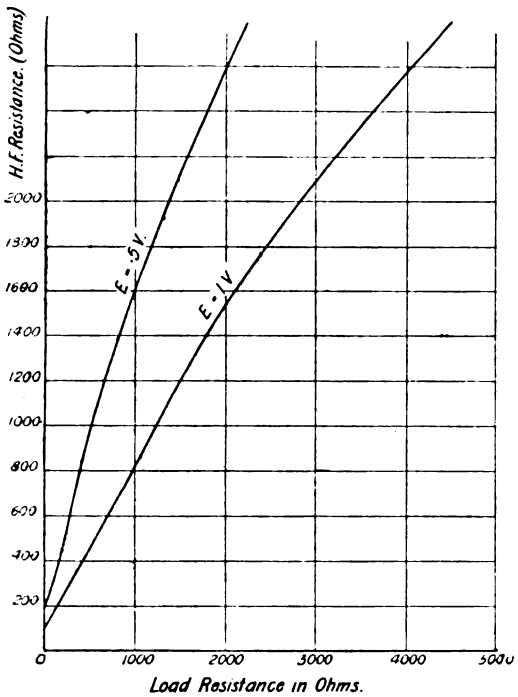

Fig. 13.

energy into D.C. energy. We want the load which will give us the best value of P_c/P_1, P_c being the continuous current power and P_1 the radio frequency power.

The maximum continuous current power is obtained when the external load is made equal to the internal resistance. The P_c reaches a very sharp maximum with a load of about 103 ohms, but P_c/P_1, which represents the efficiency of the transformation of energy, increases continuously with the magnitude of the resistance. This is calculated for the ideal straight-line case. Actually the measurements I have made on a galena detector show that a diagram of this nature will also illustrate the behaviour of a galena detector in the same respects. In other words, although the maximum continuous current energy appears to be associated with a comparatively low resistance; yet if the input energy is limited then it is probable that a much higher output of continuous current energy will be obtained with a considerably higher resistance load, because the efficiency of transformation of the A.C. energy into D.C. energy increases with the load. You will observe that the efficiency of transformation reaches a very high value. It is nearly 80 per cent. for a load of 5 000 ohms. When I first came to that conclusion I felt there must be something wrong, because one is not accustomed to regard a crystal detector as a very efficient transformer of energy. But after I had come to this conclusion, the input and output energies were actually measured by Mr. P. K. Turner by a very excellent method which he produced for the determination of performance of typical crystal detectors, and I was agreeably surprised to find that he had actually obtained higher efficiencies than those I have predicted. Therefore we are forced to the conclusion that a crystal detector, regarded simply as a transformer of A.C. power into D.C. power, is an exceedingly efficient piece of apparatus at large amplitudes and under suitable conditions of load. Efficiencies of 80 per cent. and as high as 90 per cent. can be obtained with a crystal rectifier in this transformation.

I have said that the high frequency resistance of the detector depends upon the magnitude of the continuous current load which is used in series with it. Fig 13 shows typical results for the galena detector obtained by the actual graphical analysis of the calculated form of the effective or dynamic characteristic. You will see that for small signal amplitudes, the effective high frequency resistance is higher than for large signal amplitudes. In other words, the high frequency resistance at constant load increases as the signal amplitude decreases, and for constant E.M.F. the high frequency resistance increases very rapidly as the continuous current load resistance is increased. In other words, the crystal behaves very much like an ordinary A.C. transformer. That is the most useful way to regard a crystal detector; not as a detector which allows current to flow in one direction and not the other, but as an actual transformer of A.C. into D.C. power, and it has the actual characteristics of such a transformer inasmuch as the input resistance

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or power-consuming resistance depends on the load which you put in the output circuit side.

In Fig. 14 I show the calculated effective high frequency resistance for the ideal

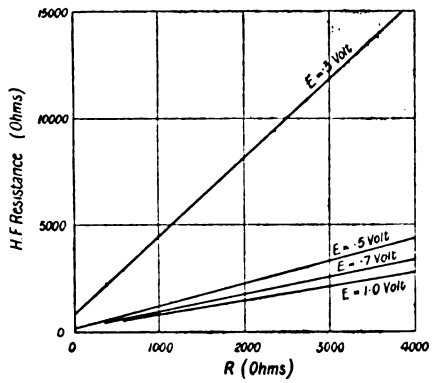

Fig. 14.

straight-line detector, which I said could be regarded as an idealisation of the ordinary crystal detector. You will see that I have been able to do this in more detail, because it did not involve troublesome experimental work, and you will see that the essential character of the result is the same, which confirms that the straight-line characteristic can be regarded as a suitable substitute, for the purpose of calculation, for actual crystal detectors. You will see that the high-frequency resistance with constant load increases rapidly as the signal amplitude increases and for constant signal E.M.F. it increases as the load resistance increases.

Fig. 15 shows the same thing calculated for a fourth power characteristic, *i.e.*, for a detector working on small amplitudes. In this case, the variation is considerably less. You will observe that with an amplitude of .1 volt, the high frequency resistance only varies from 7 000 ohms, with variation of load, to 4 000 ohms, and as the signal amplitude decreases, the effective high frequency resistance becomes more and more constant. That is a result one might expect, since for a very small signal amplitude the curvature of the characteristic is scarcely appreciable and it behaves practically like an ordinary Ohm's Law conductor.

This question of the measurement of the effective high frequency resistance of a detector is an important one for determining the relative merits of different types of detectors, but it is one of very considerable difficulty from the experimental point of view, and a matter upon which much more work still requires to be done. The only experimental method I know which is capable of practical application in a comparatively simple manner is one which has been developed by Mr. P. K. Turner, and perhaps he will say something about it in the discussion.

In the *Wireless World* a short time ago a description was given of a method of measuring the high frequency resistance of a detector based upon plotting resonance curves, the detector being connected across the resonance circuit. For reasons which by now will be quite clear, such a method will be practically useless, because the high frequency resistance depends on the signal amplitude and on the load, so that no method of measuring high frequency resistance will give very useful information if it does not take into account the variation of resistance with the conditions of operation.

I think I will trespass on your toleration for another five minutes just to outline the application of this analysis to the practical reception of radio-telephony signals. Consider, first, the case in which we have an unloaded rectifier circuit. If we plot the magnitude of the continuous current against the signal amplitude we shall obtain a curve

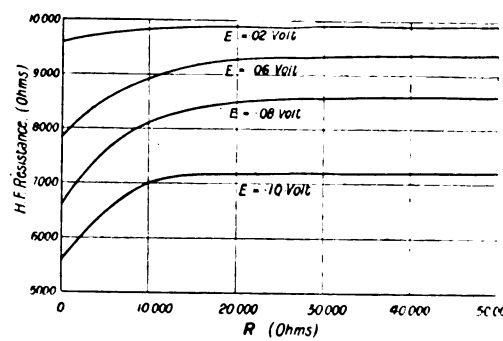

Fig. 15.

of the character of Fig. 16, which becomes approximately a straight line when the signal amplitude exceeds .3 or .4 volt. The abscissæ are not D.C. E.M.F.s, but the amplitude of the applied alternating E.M.F.

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Suppose we fix a certain signal amplitude E, we shall have a corresponding continuous current, I_c. Suppose that amplitude is modulated by an audio-frequency, as is the case in wireless telephony. We cannot

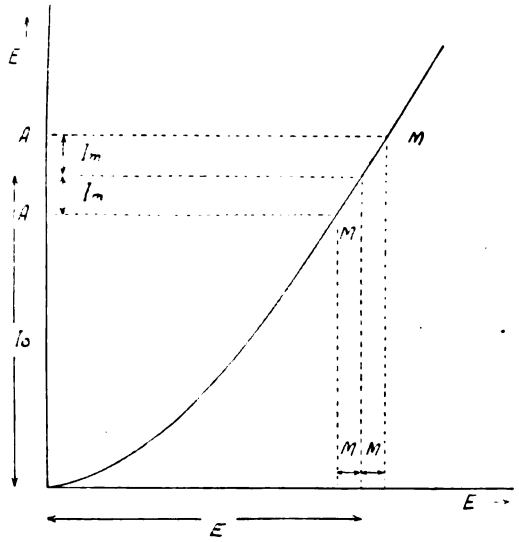

Fig. 16.

consider the general case of speech or music because that involves much too complex a wave form of modulation; but imagine we have modulation at a single frequency, and let us see what happens to the rectified current. The amplitude E is no longer constant, but varies at an audio frequency by an amount M, where M is the amplitude of the modulation. That will produce a corresponding variation of the rectified current flowing in that circuit, which can be represented by I_m.

Now, if the input amplitude varies in a simple harmonic or sine wave manner by an amount M, there will be a corresponding variation of the continuous current by an amount which is obviously M multiplied by the slope of the curve. In other words, we shall have a modulation frequency component current given by the expression:—

$$I_m = M \frac{dI_c}{dE}$$

If the characteristic is a straight line, this variation of the continuous current, which is really a modulation frequency component of the current, will obviously be a faithful reproduction of M. In other words, if we want to get pure reproduction of the modulation, it is essential that the variation should take place over a part of the characteristic which is appreciably a straight line, and that is where a crystal detector has a very considerable advantage over the valve, because actually, if I_c is plotted against amplitude, for almost any ordinary crystal detector either of the galena or perikon type, it will be found that for signal amplitudes exceeding .4 volt, the rectification characteristic becomes practically a straight line, and that means that such a detector is capable of giving singularly pure and undistorted reproduction of modulation. That is a well-known characteristic of crystal reception of broadcast telephony or music.

I am afraid I have not time to go into the variations of these rather simple analyses when we come to an inductive load in series with the detector, but briefly the position is very much the same as that which I have already described in connection with the rectification of continuous wave signals, *i.e.*, it will be found that the expression for the current can be put in the form of modulation frequency E.M.F. divided by a certain internal resistance plus a load impedance; and the optimum condition, as before, will correspond to an equality of the load impedance and the internal resistance. This latter is slightly different from the corresponding figure in the case of a continuous wave. For galena it is still very low, of the order of 100 ohms, and for perikon it is from 400 to 500 ohms. Just in the same way as the efficiency of power transformation increases with load in the case of continuous wave reception, so also in the case of modulated wave reception the efficiency of transformation of the input power into modulation frequency power increases when the load is increased beyond the apparent optimum corresponding to a maintained input potential. The result is that actually the loudest signals will be obtained with a definite load which is apparently greatly in excess of the appropriate internal resistance of the detector. Actually in nine cases out of ten this is overdone I think, *i.e.*, it is taken for granted that a telephone resistance should be of the order of at least 4 000 ohms. You will find, however, that in most cases a considerable increase of signal strength is obtained with

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lower resistance telephones provided the input E.M.F. is stepped down to avoid excessive aerial damping. However, the detailed analysis of that side of the question would take me another hour, so that I am afraid I shall have to leave it out. I hope I have been able to convey something of the essential principles of the subject to you, and if there are any outstanding points upon which you would like more information I will do my best to give it you as briefly as I can in the reply to the discussion.

The Discussion.

The CHAIRMAN: I am sure you will agree that this has been an extremely interesting lecture, which has shown us not only how the crystal detector works, but has also given us the reason why it is not very much use on very weak signals. We shall now be pleased to have discussion of the lecture.

Mr. P. K. TURNER: I have listened with great interest to Mr. Colebrook's talk. Some of it has been more or less familiar to me, because I have had the painful job of reading a rather extended form of it word by word and letter by letter and correcting printers' errors in it, and in its fully expanded form the task of going through it has been one of labour and certainly not a labour of love! Mr. Colebrook emphasised the importance of the two characteristic quantities E_c and R_c, which may be called the output characteristic quantities of a crystal, but it was not until considerably later that he spoke of the importance of the corresponding input quantity—the apparent input resistance. That is very important, as he made clear later on, but I do not know that he laid quite sufficient stress, from my point of view, on the influence of that input resistance on tuning. One often hears complaints of flatness of tuning in a crystal circuit, which is simply due to the fact that it is being used under unsuitable conditions, so that this comparatively small input resistance is overloading the circuit to which it is connected and damping it so heavily as to flatten its tuning. That is got over in the way Mr. Colebrook suggests, by practically using a high frequency transformer in front of it.

The effect of a potentiometer may be very peculiar in this connection. I have been using crystals a lot for broadcast reception—incidentally those who have not tried crystals under proper conditions have no idea of how good broadcast reception can be with them—and at two miles from London I have been using a high frequency valve in front of a crystal, so that the high frequency E.M.F. applied to the crystal was thus the same as that mentioned by Mr. Colebrook, 1 to 2 volts. While using that circuit on more distant stations I thought, to increase the efficiency, that I would apply a potentiometer, because I had realised some time ago that there was the D.C. E.M.F. effect due to the load in the crystal circuit—a D.C. voltage coming on to the crystal itself. I realised it was in the wrong direction from the potentiometer point of view, so I used an applied E.M.F. on a galena crystal (which nominally requires no potentiometer), in the hope that it might be made to work better. In the particular case I put the detector across the "tuned anode" coil of a valve, and I got very much louder signals by putting the potentiometer farther still the wrong way! It took me some time to realise what Mr. Colebrook has brought out in his lecture to-night; namely, that I was diminishing the efficiency of my rectification as such, but was increasing the H.F. input to the crystal. In effect I was putting more reaction on to the set by increasing the H.F. input resistance of the crystal, and thus taking off damping from the valve. Nevertheless in such a case as that one can sometimes get better effects by using potentials on the crystal, but you must allow for the fact that you are thereby increasing the damping on the circuit. With regard to the actual measurement of crystals, I gave some account of that here not long ago. The method of measurement is, in essence, quite a simple one, but in practice it is perhaps not quite so simple. All high frequency resistance measurements are unpleasant. They require much more care than anybody usually has time to give them.

The highest efficiency I found was a ratio of output power to input power of 0.94, or 94 per cent. on one point of one crystal. On galena crystals, of which I have tested three or four dozen, I suppose the average efficiency is about 50 per cent. taking the crystal point contacts as they come without actually searching for them. That efficiency is at voltages above 0.5 volt of the high frequency input. At 0.1 volt input the efficiencies are in the neighbourhood, as a rule, of 10 per cent. Measurements in that neighbourhood however are rather vague, because one has to be prepared to measure something rather less than 1 microwatt of high frequency power, and that is not easy without elaborate instruments which one does not possess. There is one other little point in connection with the use of valve amplification after the crystal detector, and that is the question of the transformer ratio. Mr. Colebrook has shown in an article of his that the use of a transformer after a crystal need not by any means introduce distortion. Personally, I am of the view that the use of a transformer coupling between valves in low frequency work is, *for present-day practical purposes*, very nearly if not quite as satisfactory—in fact I will say quite as satisfactory—as resistance amplification, for reasons I do not want to fight out now.

Whatever one may think of transformer coupling between valves, there is very little doubt that transformer coupling after a crystal is, for all effective purposes, free from distortion. The ratio of the transformer for galena should be high, about 8 to 1 is a good ratio which I have worked out in practice.

Curiously enough, in a conversation with a well-known wireless engineer the other day, he told me he had been experimenting on the same thing and

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had found that a 2.7 to 1 transformer was the only one worth using after a crystal. We argued a long time about it before I found out that he was speaking of carborundum. Mr. Colebrook has not done any work on carborundum, which is a pity, but the input resistance of carborundum is known to be extremely high. What the R_c is I do not know, but I suspect, from what I know of carborundum, that that was the source of difficulty in the case mentioned. Whereas galena is 100 and perikon 500, I suspect that with carborundum it is about 3 000 or 4 000 ohms. There is a very nice point in this connection, as to whether one could increase the transformer ratio still further, but I am afraid that is too long a problem to go into now. One other point is that I think it would be interesting if Mr. Colebrook, when he has some spare time on his hands, would try the quantitative effect of applied D.C. voltages—potentiometer voltages—on the varying characteristics of a crystal.

Mr. E. H. Robinson: It has occurred to most of us at some time or other to use two detectors and make use of full cycle rectification, rectifying both halves of the H.F. cycle. The results of my own trials in this connection however have been negative; there has been no increase in signal strength; and it would therefore be interesting if Mr. Colebrook, from his own knowledge, could tell us whether there is any theoretical reason to expect an advantage from full cycle rectification with crystal detectors.

Mr. P. R. Coursey: The long time during which crystal detectors have been studied, really only emphasises the mystery underlying their action. Crystal detectors have been known for a good number of years, and research has been carried out on them for many years but we still seem to have a great deal to find out about them. There is only one point that I would like to refer to that was mentioned by Mr. Colebrook, namely, that it is not always best to put the polarising potential where one thought it should be, namely, where the change of curvature was greatest. In that connection I do not know whether he has noticed a paper which I read before the Physical Society some ten or twelve years ago in which that matter was experimentally investigated from the point of view of the relationship between the sensitiveness and shape of the second differential curve of the characteristic curve. In those cases tested at that time there was almost complete agreement; where the greatest sensitiveness occurred its curve of variation agreed almost exactly with the shape of the second differential of the static characteristic. That fact may have been due partly to the conditions of experiment that were common at that time. In those days I was working at a college laboratory, and one's views of the proper conditions for experimenting were different from what one has, perhaps, nowadays. It was then considered the proper thing to use a resistance in the output circuit—a telephone resistance or galvanometer resistance as the case may be—which never exceeded 100 or 120 ohm for galena and never exceeded 1 000 ohms with perikon, so that that would considerably affect probably the results obtained with different potentials supplied to the crystal. I certainly think that if more investigations of the type Mr. Colebrook has given us to-night were carried out we ought to learn more about the operation of crystal detectors.

Mr. Colebrook in replying to the discussion said: I was asked about carborundum. I have done a certain amount of work with this, but came to the conclusion that if in any circumstances it appeared to be a comparable substitute for the two types of detector I have mentioned, it can only be due to the fact that the whole circuit conditions were less inefficient for carborundum than for the others. In itself I think carborundum is likely to be inefficient compared with either of the other two, and the reason for that is easy to see—I think Mr. Turner practically gave it himself. The maximum continuous energy obtainable for a given single amplitude is obviously in the form

$$P = \frac{E_c^2}{4R_c}$$

That is the continuous current power you get when you make your load resistance equal to the internal resistance. It is obviously desirable therefore that R_c should be small, and that is the secret, actually, of the very high possible efficiency of the galena detector; I mean its high efficiency if it is properly used. This low internal resistance will be a positive drawback if it is *not* properly used and if the signal voltage is not suitably stepped down to reduce the load on the receiving circuit; but if it is properly used it is desirable that R_c should be low. Carborundum, as Mr. Turner has indicated, has an exceedingly high value of R_c. I have forgotten the figure but I think it is thousands of ohms, compared with hundreds of ohms in the case of galena.

Then with regard to the effect of full wave rectification with two detectors, mentioned by one speaker, I have not gone into it very thoroughly myself experimentally, but I think it is exceedingly unlikely that anything is to be gained by full wave rectification. Properly used, the single detector is capable of giving very high efficiency of transformation, and I do not think you can increase that efficiency, even under ideal conditions, by more than a few per cent. as the result of using full wave rectification, because you are either introducing twice the load or you only apply half the E.M.F., and the efficiency falls off as the E.M.F. is reduced. Therefore from both the theoretical and practical points of view and also from the point of view of simplicity, I do not think full wave rectification is likely to have very much advantage from the ordinary listener's point of view.

The effect of D.C. voltages is certainly an interesting point, and Mr. Turner asked what effect the applied potential would have under suitable load conditions. It is a matter that I certainly will go into, but I have sufficient faith in this ideal straight-line representation of the galena detector working under large amplitudes, to investigate it on the theoretical basis of that characteristic. I have faith in that characteristic because I have made a considerable number of experiments on actual detectors and compared the results with the results that would be deduced from simple straight-line characteristics of that kind; and provided your signal amplitude does not fall below half a volt, the theoretical and predicted results

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are in very close agreement. That is a considerable advantage from the practical point of view, because you can go on making all kinds of conditions and you can predict quite accurately what will be the effect of these conditions.

Mr. Coursey asks about something of the same kind, *i.e.*, the effect of potential on the detector, and spoke about the conditions of testing. Of course, any conclusions that are drawn from the operation of detectors with a maintained source of E.M.F. are likely to be quite misleading when you use a detector in the ordinary way across the tuning inductance of an aerial, because there the E.M.F. depends almost entirely on the load you are imposing by means of the detector, whereas with a maintained E.M.F., which is maintained in spite of the load you impose upon it, the conditions are totally different, and totally different conclusions would be reached. With a maintained E.M.F. a low resistance of the order, as Mr. Coursey said, of 200 or 300 ohms, would be the most suitable to use, because such a resistance would give you the maximum output energy, but if your input condition is not one of constant potential but one of constant energy, as it is mostly in the case of ordinary crystal reception, the analysis depending on the equivalent of internal and external resistance breaks down completely.

Mr. P. K. TURNER: In rising to propose a vote of thanks to Mr. Colebrook. I have to thank him not only for delivering a paper to-night but for utilising some very large resources and a considerable amount of his own brain-power for the space of about a year in order to prepare for this. We realise that there is a lot of fairly complicated mathematical analysis behind tnis paper, and there is also a very great deal of experimental work of a most difficult kind. I do not think I am—in fact I am sure I am not—giving away any secrets if I say that in the other part of Mr. Colebrook's recent work (which has not been dealt with to-night from the lack of time), namely, valve detection, the final conclusion which interests me personally more than any other is that in practically every workable condition the crystal is *the* distortionless detector provided it is used under proper conditions.

It is an interesting point that "the proper place to use a crystal is after a valve," where you have a large input and also you can have a circuit with maintained voltage by using reaction on the valve and thus compensating for the damping due to the crystal. That point is one which I should like to see brought thoroughly home to every member of this Society who is interested not only in long distance work but also in broadcast reception. The use of a crystal after a valve is the best way I know to get purity of tone, and I hope that the emphasis which has been laid on the crystal—which has always been rather looked down upon—by this paper to-night, by somebody who has been doing very difficult investigation work on it, will lead those of you who are interested in broadcast reception to try it, and for that reason above all others I think we should thank Mr. Colebrook very much.

Mr. FOGARTY: I should like to second the proposal that we give a very hearty vote of thanks to Mr. Colebrook for his very interesting paper. The crystal has been a subject for study for a very large number of years, as Mr. Coursey has pointed out, but we still seem very far from knowing all there is to know about it. Until recent years I think we have been perhaps a little too prone to rush to the valve as a solution of all difficulties in connection with reception, and it is therefore refreshing and good for us to be reminded that the older method still has something to recommend it. This is hardly the time to re-open the discussion, but I should like to say that perhaps we all agree with Mr. Turner that a crystal will give us less distortion in reception than the valve, and it may be that the reason it is not used as much as it might be is that whilst it gives us undisturbed reception while it works, it is inclined to go out of action and wants a lot of touching up or re-setting or tickling as it is called. That may be got over with special arrangements, some of which enable detectors to be worked in fixed positions. If that is so then I suggest it is high time that those who are engaged on these new developments should make them known to the Society by means of a paper. I am sure the Papers Committee will be very glad to give an opportunity for the early reading of a paper on this subject. With these few remarks I have much pleasure in seconding the vote of thanks to Mr. Colebrook.

The vote of thanks was carried with acclamation.

The CHAIRMAN announced the names of one transfer and three new members for election and one Society for affiliation and also announced that the next Ordinary Meeting, the final for the session, will be held on Wednesday, 24th June.

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Some More Valves Tested. [R333·009·

We have recently tested about a dozen valves, some of which are described below, the remainder being held over until our next issue. Those dealt with now are the A.R.D.E. H.F., the A.R.D.E. L.F., the P.V.5 D.E. and the P.V.6 D.E., all by the Edison Swan Electric Co., Ltd., and the D.E.3b, by the Marconi-Osram Valve Co., Ltd.

A.R.D.E. H.F. and A.R.D.E. L.F.

THE well-known Ediswan A.R.D.E. is now made in two modifications, intended respectively for H.F. and L.F. use. They are respectively distinguished by a red and green line on the bulb. The construction of the bulb and electrodes appears to be substantially the same as in the old pattern A.R.D.E., the bulb and the electrodes being cylindrical.

The difference between the two valves is presumably in the actual dimensions of the electrodes.

A.R.D.E.-H.F.

Fil. Volts. E_f	Fil. Cur. I_f	Sat. Plate Cur. I_s	Anode Impedance. R_a	Voltage Ampli. μ	Power Ampli. P $\left(=\frac{1\,000\mu^2}{R_a}\right)$	Filament Efficiency. F $\left(=\frac{I_s}{\text{Watts.}}\right)$
1.4	.25	1.6	50 000	8.3	1.4	4.5
1.6	.27	4	43 000	10.0	2.3	9.0
1.8	.285	9	28 000	9.3	3.1	17.5
2.0	.30	15	24 000	9.4	3.75	25.0

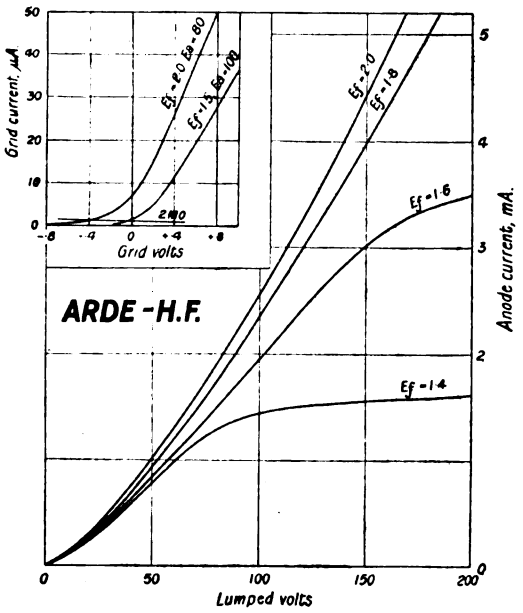
The rating of the filaments of both valves (which come in our 235 class) is the same—1.8-2.0 volts, 0.3 amp—while the anode ratings are 20-100 volts and 30-100 volts for the H.F. and L.F. respectively. They were both tested at four values of filament voltage, and the corresponding current consumption is shown in the accompanying tables. As will be seen, the makers' ratings are accurately borne out in practice.

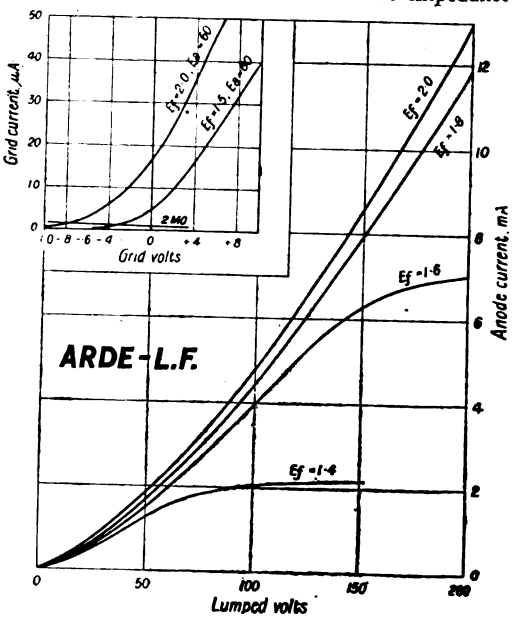
Dealing now with the H.F. valve it will be seen that the saturation plate current rose from 1.6 to 15mA. The impedance is on the high side, ranging from 50 000 to 24 000 ohms, but this is accounted for by the high magnification obtained, which is in the neighbourhood of 9 or 10. The corresponding power amplification rose to 3.75 at 2.0 volts on the filament.

Fil. Volts. E_f	Fil. Cur. I_f	Sat. Plate Cur. I_s	Anode Impedance. R_a	Voltage Ampli. μ	Power Ampli. P $\left(=\frac{1\,000\mu^2}{R_a}\right)$	Filament Efficiency. F $\left(=\frac{I_s}{\text{Watts.}}\right)$
1.4	.24	2.1	28 000	4.7	.78	6.2
1.6	.26	8.0	19 500	4.5	1.05	19.0
1.8	.28	13.0	13 000	5.2	2.1	26.0
2.0	.30	22.0	11 500*	5.3	2.5	37.0

* At 200V.

As this is an H.F. amplifier it will not have to deal with a very large amount of power, so that 1.8 volts on the filament would probably be quite suitable, especially as the increase of power amplification obtained by pushing up the filament voltage to 2 is not very great, and the curve for 1.8 volts shows a good straight portion. On the other hand, owing to the sudden rise in the impedance





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as the voltage is diminished from 1.8 to 1.6, the power amplification is much less at the latter voltage.

From the grid-current curve it will be seen that the valve should make a good detector, a 2MO leak being about correct.

The L.F. valve, as was expected, gave a higher output, rising from 2.1 to 22mA. The impedance was found to be much lower than in the case of the H.F. valve, as was also the voltage amplification, which ranged from 4.7 to 5.3.

The power amplification rose from 0.78 to 2.5. From the curves obtained it will be seen that the one corresponding to 2.0 volts on the filament begins to straighten out nicely at about 150 volts. If we assume a grid amplitude of 3 volts the grid must be biased to at least 4 volts. As the amplification factor is about 5, the corresponding plate voltage will have to be $150+(5\times 4)$, or 170 volts. The valve should then function well as a distortionless amplifier. From the grid current curves it will be seen that the H.F. valve will be by far the better detector. The two valves are priced at 14s. each.

P.V.5 D.E.

This is a dull-emitter power valve. The makers rate it as follows: Filament, 5.0 volts, 0.25 amp; anode, 50-150 volts. We should therefore class it as a "625" type valve.

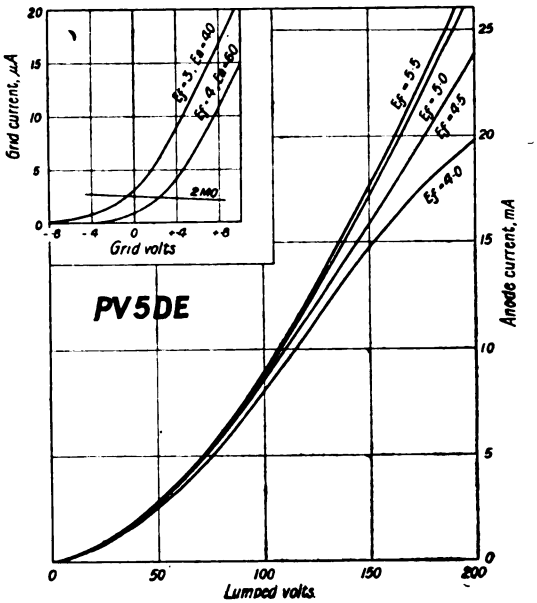
Fil. Volts. E_f	Fil. Cur. I_f	Sat. Plate Cur. I_s	Anode Imped-ance. R_a	Voltage Ampli. μ	Power Ampli. P $\left(=\frac{1\,000\mu^2}{R_a}\right)$	Filament Efficiency. F $\left(=\frac{I_s}{\text{Watts.}}\right)$
4.0	.25	25	7 000	4.2	2.5	25
4.5	.265	40	6 300	3.8	2.3	33
5.0	.28	70	5 000*	3.1	2.0	50
5.5	.295	100	4 600*	3.0	2.0	62

* At 200V.

The bulb is pear-shaped and rather squat, with a fairly large diameter. The electrodes are vertical, the anode and grid being large and flattened, as is usual with this type of valve. The filament is of the "hair-pin" type, with a special support fixed to a glass bridge piece held by wires extending from the anode and grid.

The valve was tested at 4.0, 4.5, 5.0 and 5.5 volts, and the first thing noticed was an exceptionally high output, the saturation plate current rising from 25 to over 100mA! In fact, the latter figure is quite conservative, as we could not make sure of the saturation current at this filament voltage. We were at first inclined to the belief that the valve was slightly "soft," but could see no trace of "blueing." We are now of the opinion that this high output is not due to softness, but to the construction of the valve.

It would be seen that though the impedance is low, the amplification factor is low also, with the result that the power amplification is below the average for this type of valve. However, in the last stage of an amplifier, where the ability to handle a large amount of power is essential, this valve should do well. Nothing much is gained by running the filament above about 4.5 volts, since the curve for this voltage shows a good straight portion round 150 volts on the anode. From the



grid current curve it will be seen that the valve should make a fairly good detector, but the leak should be rather more than 2MO for best results. The price is 22s. 6d.

P.V.6 D.E.

This is a 2-volt power valve, intended for use in sets employing valves of the A.R.D.E. type in the other stages. The makers rate it: Filament 1.8-2.0 volts, 0.4 amp; anode 60-120 volts. It would therefore be put in our "240" class. The bulb is pear-shaped, and the electrodes are vertical and similar in construction to those of the R, A.R. or A.R.D.E. types, though, of course, different in dimensions.

We tested the valve at voltages of 1.4, 1.6, 1.8 and 2.0, and found the current consumption to be somewhat greater than the rating, bringing the valve, in fact, within the "245" class. The saturation current ranged from 4 to 22mA, the impedance falling from 25 000 to 10 700 ohms,

Fil. Volts. E_f	Fil. Cur. I_f	Sat. Plate Cur. I_s	Anode Imped-ance. R_a	Voltage Ampli. μ	Power Ampli. P $\left(=\frac{1\,000\mu^2}{R_a}\right)$	Filament Efficiency. F $\left(=\frac{I_s}{\text{Watts.}}\right)$
1.4	.40	4	25 000	3.3	0.45	7.2
1.6	.425	7.5	20 500	6.2	1.9	11
1.8	.45	14	14 000	5.6	2.24	17.5
2.0	.475	22	10 700	5.0	2.32	23

and the μ ranging from about 3.3 to 6.2. The power amplification was greatest at 2.0 volts, being then 2.32.

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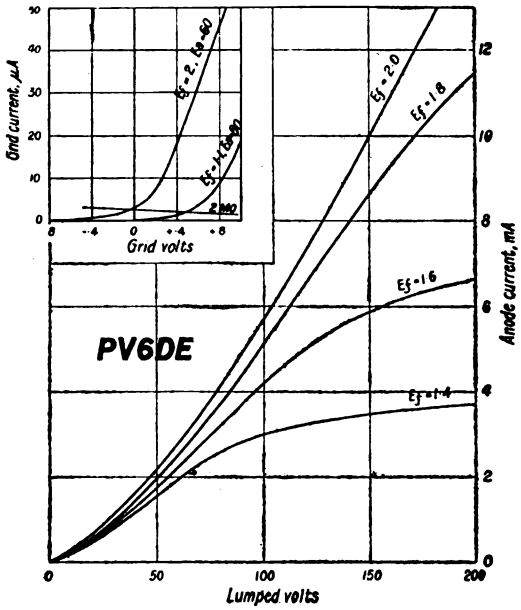
In all respects the valve is a normal member of its class. The rating of 60-120 anode volts is rather low, but as the curves obtained begin to straighten out nicely at about 100 volts (total) this should be roughly correct.



If we allow 4 volts grid swing, and bias the grid to —5 volts, the plate voltage should be $100+(5\times5)=125$ (assuming $\mu=5$). This is certainly an advantage, since a small high tension battery is an important consideration when using power valves, and those who need a small valve of this type, able to deal with a moderate power at a reasonable cost, should bear the P.V.6 D.E. in mind.

As a detector it should work very well, using 2.0 volts on the filament, and a 2MO leak. The price is 18s. 6d.

D.E.3b.

This valve is designed to hold the same relation to the D.E.3 as the D.E.5b does to the D.E.5. It is intended for use mainly in resistance-coupled L.F. amplifiers, where a high magnification in the valve itself is important, and the corresponding increase in impedance is not so detrimental. In construction it is similar to the D.E.3, and the rating is the same, namely: filament, 2.8-3.0 volts, 0.06 amp; anode 120 volts maximum. According to our classification, it is therefore a "306b."

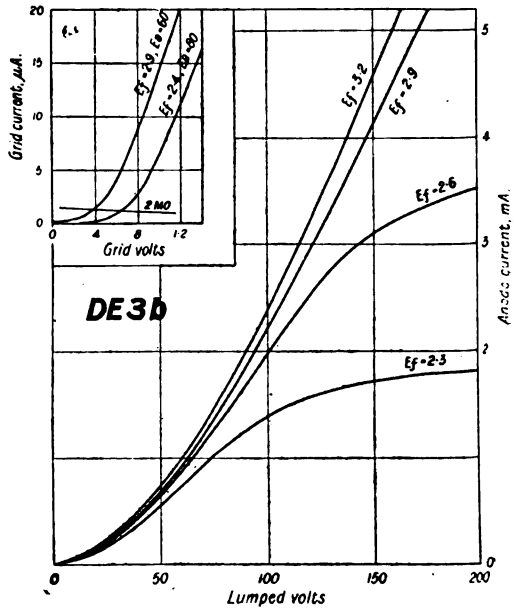
It was tested at filament voltages of 2.3, 2.6, 2.9 and 3.2, the current consumption ranging from 59 to 70mA. The output, which ranged from 2.0 to 11.0mA, is quite sufficient for this type of valve, as it is not intended to handle much power. The anode impedance fell from 50 000 to 22 000 ohms, the amplification factor ranging from 13.3 to 10.2 and the power amplification from 3.5 to 4.8.

Apparently nothing is gained by running the valve at a filament voltage greater than 2.9. Though the μ is high, it is not so high as that of the D.E.5b, which is in the region of 20. The impedance is correspondingly low for this type of valve.

From the curve for 2.9 volts on the filament, it is seen that at 130 volts (total) on the anode the valve will be working on a straight portion of its curve. We may assume a grid swing of only 1 volt from the previous valve, hence the bias need not exceed 1.5 volts, bringing the necessary plate voltage up to 145. This is above the maximum recommended by the makers, and should not be over-stepped, since this type of valve has a coated filament which is easily destroyed by bombardment should the residual gas in the valve become ionised. However, if the voltage is reduced to 120, no serious effect due to the slight curvature of the characteristic should be noticeable, especially as the effect of the high resistance in the anode circuit comes into play.

Fil. Volts. E_f	Fil. Cur. I_f	Sat. Plate Cur. I_s	Anode Impedance. R_a	Voltage Ampli. μ	Power Ampli. P $\left(=\frac{1\,000\mu^2}{R}\right)$	Filament Efficiency. F $\left(=\frac{I_s}{\text{Watts.}}\right)$
2.3	.059	2.0	50 000	13.3	3.5	15
2.6	.063	4	36 000	12.0	4.0	24
2.9	.067	7	26 000	11.2	4.8	36
3.2	.070	11	22 000	10.2	4.8	50

This valve could also probably be used as an H.F. amplifier, since it has a good high μ and the impedance is not unreasonably high. As a detector it should also function well with a 2MO



leak—in fact, the only duty that it must *not* be expected to perform is that of an L.F. amplifier with ordinary transformer coupling. The price is 16s. 6d.

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Fading Measurements.

By E. A. Anson (20A). **[R113·1**

In this and the succeeding article are given interesting data regarding the fading of signals in connection with various geological and meteorological conditions.

IT is well known to a large number of listeners that signals from the more distant stations are subject to variation in strength in a more or less regular manner. Unfortunately the ear can only detect large variations in sound intensity, and, in addition, different ears give varied results.

For useful measurements involving a space of time of, say, twenty minutes, the aural comparison is very crude, as the standard of sound strength at the end may be quite different from the standard at the beginning.

There are several methods of measuring signal strength by instruments. The Einthoven galvanometer, with a period of a few thousandth part of a second and capable of detecting .000 000 000 015 of an amp D.C., is probably the best. It is quite costly, however, about £100 or so.

As money was an important limiting factor in these tests, it was necessary to use a method in which quite cheap accessories, that might be found in most experimental stations, could be employed. There are several such methods; one is to make use of grid bias in a valve receiver, such that when no signals are passing the plate current is zero, or near enough to give no reading on a microammeter. This meter, in series with the plate current circuit, will then indicate any flow of current caused by altering the grid potential.

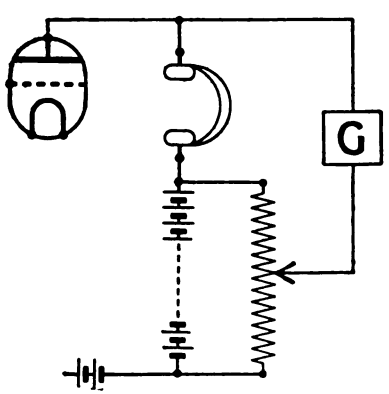

Fig. 1.

Yet another method is to balance out the steady D.C. plate current by a potentiometer across the H.T. battery, as in Fig. 1. Unless this potentiometer is of very high resistance (say, 10 000 ohms), however, the resulting readings on the galvo may be affected by the H.T. battery running down.

By these two methods fairly good comparison of signal strength from day to day may be made, but four or five valves are required to get results, and even then very weak signals are rather erratic in their effect on the circuit. For the tests discussed in this article it was only desired to compare signal strength for about a space of twenty minutes on any given station. The method adopted is shown diagrammatically in Fig. 2.

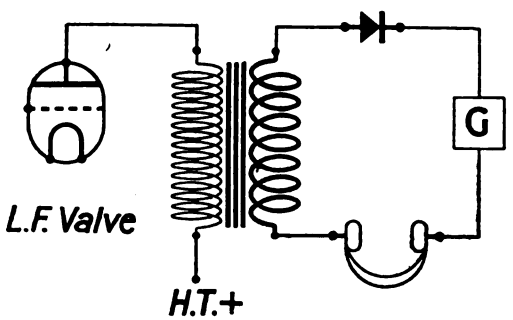

Fig. 2.

The H.F. part of the receiver is used in an oscillating condition to get a steady, audible beat with the incoming carrier wave, and a crystal detector is used to rectify the resulting alternating L.F. currents to D.C. Connected in series with the crystal is a microammeter. The particular one used gives full scale deflection for 15μA, and in series with this is a pair of headphones for tuning purposes. A complete wiring diagram is given in Fig. 3. The actual receiving instrument used had switching arrangements whereby the L.F. valve could be cut out and only the H.F. and detector used.

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This arrangement for measuring signal strength is very sensitive, in fact, signals that are quite weak in the phones give an appreciable reading on the meter.

adjusted too critically, otherwise mush, etc., affects the readings, while a quite small atmospheric gives a full deflection, and throws the needle off the scale.

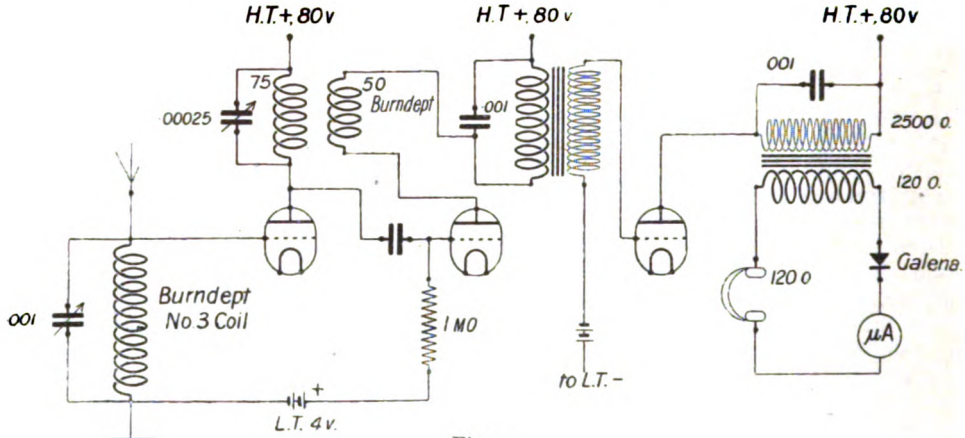

Fig. 3.

A3BQ, situated in Australia, gave a 10mm. (5μA) deflection on the galvanometer, and never dropped below 2μA for a period of five minutes. Most of the B.B.C. stations can be made to give full-scale deflection using two valves only, but reaction must not be

The microammeter actually used is of the suspended coil type, and has a coil resistance of 103 ohms; it is fitted with a pointer about 2 inches long, it has a period of 15 seconds, and a figure of merit about 6. Compared to a Cambridge AM galvo, with a figure of 80 and giving 1 mm. swing at 1 metre for .001 8μA, it will be seen that it is not necessary to use a supersensitive instrument.

The two maps referred to on page 648.

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The instrument in question was obtained from Heayberd & Co.

A full deflection of 30mm. (15μA) is obtained from a central zero or, put differently, the metre will measure up to 200 megohms insulation resistance at 100 volts. For instance, my aerial resistance to D.C. current on a damp day is 80 megohms,

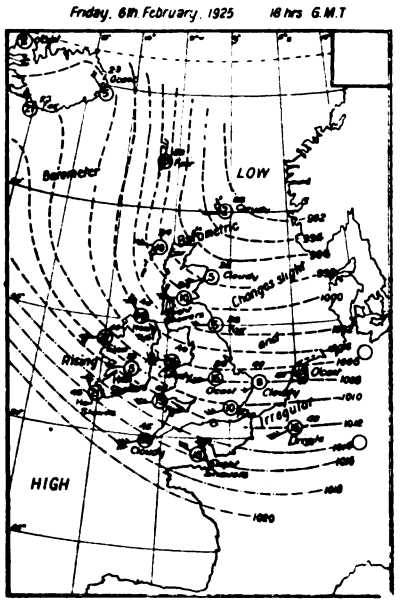

Chart I.

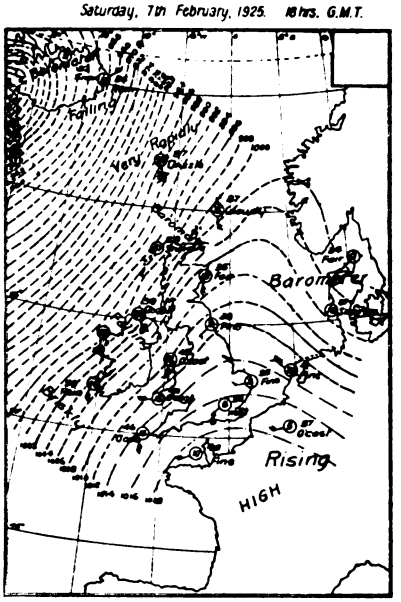

Chart II.

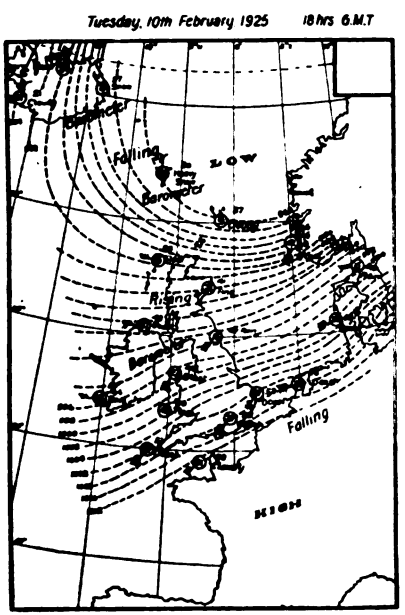

Chart III.

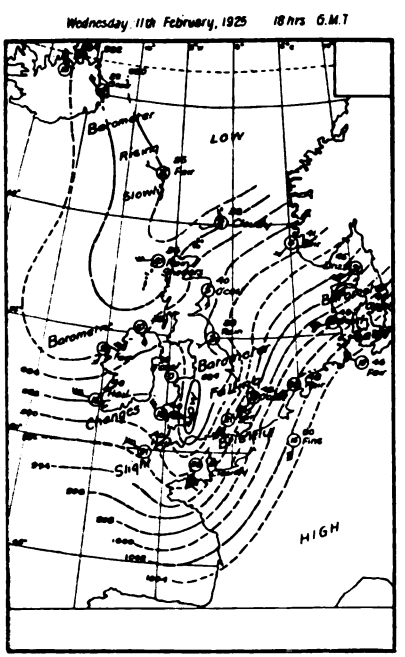

Chart IV.

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giving a deflection of 1 microamp at 80 volts. The insulators are of glass, and the lead-in enters through a hole in a pane of glass. The aerial consists of 100 ft. 7/22 single copper, and is at an average height of 30 ft. The earth, which consists of 6 7/22's buried under the aerial and earthed to the water supply at the far end, has a resistance of about 15 ohms at 300 metres.

The locality at which the tests were made is on the seaboard, flat and treeless and rural. In an area of 40 square miles north of the station there are no other receivers, as this area covers the Firth of Forth. In three or four square miles to the southward there are only four or five other receivers, and none of these is within a mile. Such tests

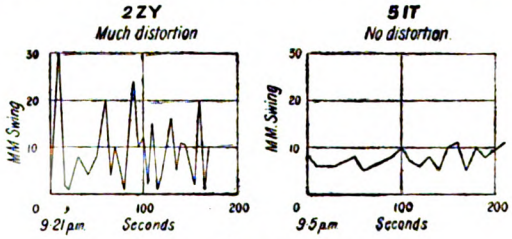

Fig. 5.

as these cannot be carried out in congested areas, as local oscillation causes erratic results. In order to assist readers in comparing the various geological conditions, etc., two maps are given (see p. 646). These show the geological features and mountain

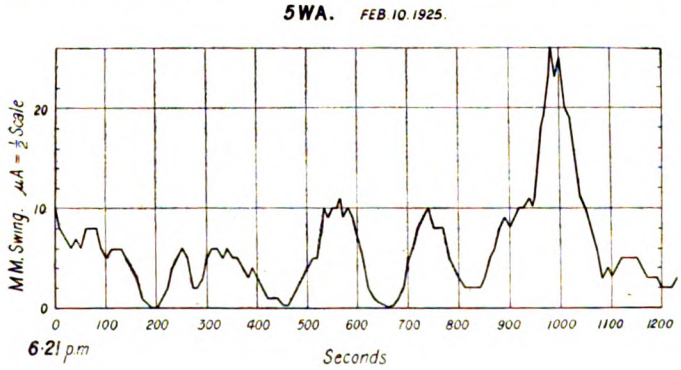

Fig. 6.

systems that the waves traverse. It will be noted that the ground contains coal at the receiving end; in fact, this area is riddled

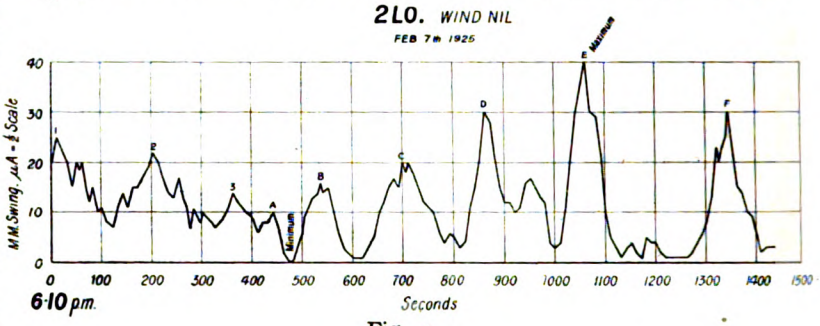

Fig. 4.

with coal mines, and the coal in places lies only a few yards from the surface.

As regards practical operation, a certain amount of patience is required to get good records, as the crystal sometimes goes on

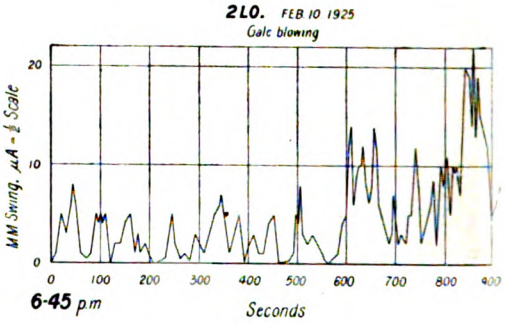

Fig. 7.

strike after a few minutes and refuses to rectify. However, once a good spot is found it will remain operative for hours. A thermocouple of 40 S.W.G. Eureka and copper was tried, but was found nowhere near as sensitive as the galena crystal.

Some very interesting fading curves were obtained. These should be studied in conjunction with the weather maps (Charts I, II, III & IV), which show the weather conditions at the time the curves were made. The weather conditions on the evening before the tests were made are shown in Chart I, the pressure S.W. of the British Isles being high, and low to the N.E. It will be noted that these conditions are

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much the same in all the charts, except that the high and low areas move slowly eastward.

A fading curve for 2LO for 27th February, 1925, taken for a period of twenty minutes,

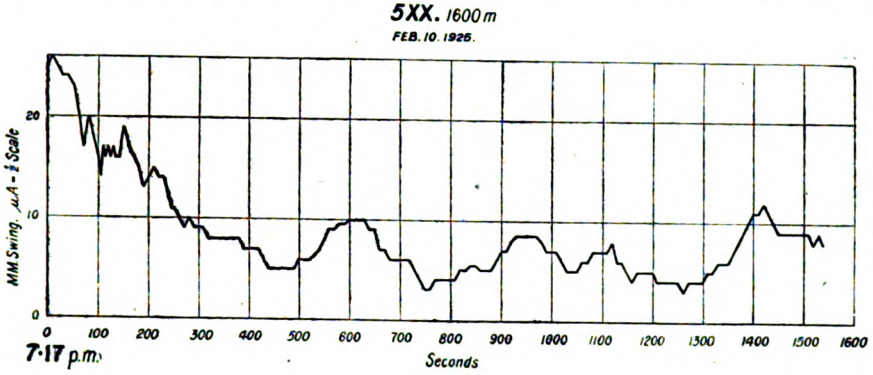

Fig. 8.

is shown in Fig. 4. The most notable feature about this curve is that the maximum peaks follow each other with a certain regularity, much like the behaviour of a pendulum would do under a suitable impetus regularly applied. Peaks A, B, C and D steadily increase until a maximum is reached at E, when the maximums begin to diminish as at F, probably falling away in the manner shown at 1, 2 and 3.

This gives a time interval from maximum peak to maximum peak of about 23 mins. The rises appear to be more irregular than the falls; also it is perhaps noteworthy that the signals appear to *recover after* a "fade" more rapidly than the original

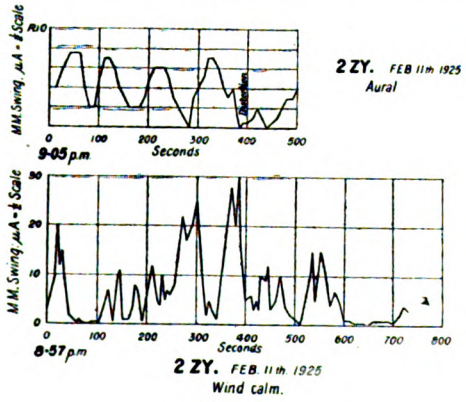

Fig. 9.

fading took place. I think this is quite noticeable even on the loud-speaker or the phones.

Fig. 5 gives a curve for 2ZY and 5IT, both taken on the same evening and at nearly the same time. 2ZY fades so suddenly and frequently that speech is at times much distorted and chopped; 5IT is much steadier and speech is clearer.

A further batch of curves was taken on 10th February. On this date there was a strong gale blowing, whereas on 7th February the wind was almost nil. Probably tuning-capacity variations, due to a swinging aerial, account for the erratic minor variations in these curves, but distinct rhythm at the peaks is noticeable. It is remarkable that 5WA (Fig. 6) gives a much steadier curve than 2LO (Fig. 7), although they were taken within 30 minutes of each other and with the same gale of wind. This curve behaves like that of 2LO on 7th February, but the maximum to maximum period is about 17 minutes, as compared to 2LO's 23 minutes.

Even the high power station is not immune from fading; in fact, at times speech on the loud-speaker becomes much distorted. Its curve (Fig. 8) is steadier and varies slowly and definitely. The maximum to maximum period appears to be about 45 minutes.

On 11th February the weather chart (IV) shows slightly more complication over England, as one of those secondary depressions is doing its best to get a hold on Wales. For this date 2ZY's curve (Fig. 9) is remarkable for the peculiar double-fade effect on the top of all the peaks. The maximum to maximum period would appear to be 17 minutes.

An aural curve of this last station is shown as an interesting comparison. Whilst it is fully realised that these few efforts on this baffling problem of fading do not appear to lead anywhere, it is thought that there is a little that can be learnt from the various curves, which also serve to show that quite interesting results may be obtained with simple circuits and instruments.

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Some Recent Observations on Periodic Fading and the Night Effect.

By Paul D. Tyers. **[R113·1**

ALTHOUGH the phenomenon of fading has been known for considerably more than ten years, there appears to have been but little systematic observation if one is to judge by the scant amount of literature available. This is due, no doubt, to the fact that it has been nobody's particular business to investigate the subject, and it is only within recent years that the radio engineer has realised that a satisfactory solution of the problem is likely to prove of paramount importance. Associated with short-period variation of field intensity, or simply "fading" or "swinging" as it is more popularly termed, is the "night effect" or distortion of a modulated carrier wave. This distortion is of a peculiar nature, and is more easily appreciated by actual hearing than by an attempt to define it.

While it seems probable that a satisfactory explanation of the phenomenon is more likely to be derived from definite organised systematic observations carried out at a large number of different points, than from a few isolated records, there seems to be no reason why the latter, when correlated with other records, should not prove of value. As the writer was recently fortunate enough to observe some rather peculiar effects, the following short notes have been prepared in the hope that they may prove of interest to those who are at present investigating the subject.

The observations were made on several British broadcasting stations, and in addition, on some of the Continental stations. Those detailed here have been picked out from a large number as being the most interesting. As it was desired to note both the variations in field intensity and the quality of the modulation, means were provided for measuring the rectified current, and subsequently amplifying it, a loud-speaker being included in the output circuit of the amplifier.

The fundamental circuit which was employed for these observations is shown in Fig. 1, and it will be seen that the method consists essentially in amplifying the received oscillations by a valve *V*. The anode circuit of this valve contains the circuit *LC*, which is shunted by a crystal rectifier *D* and microammeter *M*. It is important when making observations on signal strength to ensure

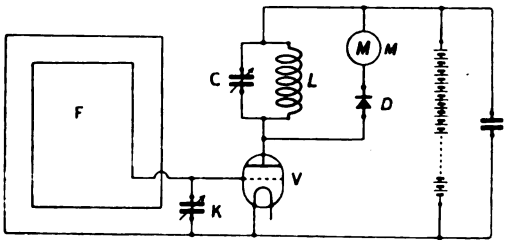

Fig. 1.

that any tendency to self-oscillation in the valve receiving system is reduced to a minimum, as variation in conditions might materially increase any inherent reaction effects, which would be liable to introduce error in recording the rectified current. The resistance of the crystal rectifier and the microammeter which is shunted across the circuit *LC* lowers the resonance peak of that circuit considerably, and consequently the arrangement is very stable. It will be noticed that a frame *F* tuned by a condenser *K* was used for the input circuit; this point will be referred to later.

The complete circuit employed is shown in Fig. 2, and it will be seen that a resistance *R* is included in the rectifier circuit. The microammeter *M* measures the steady value of the rectified current, while the audio-frequency variations cause potential differences to be set up across the resistance *R* connected to the input of a resistance-coupled amplifier containing a loud-speaker in the output circuit. By this means it was found possible to observe any change in the quality of the speech or music simultaneously with the change in the received current.

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A brief account of some of the results obtained will now be given, and any deductions which can be drawn will be left to the end of these notes.

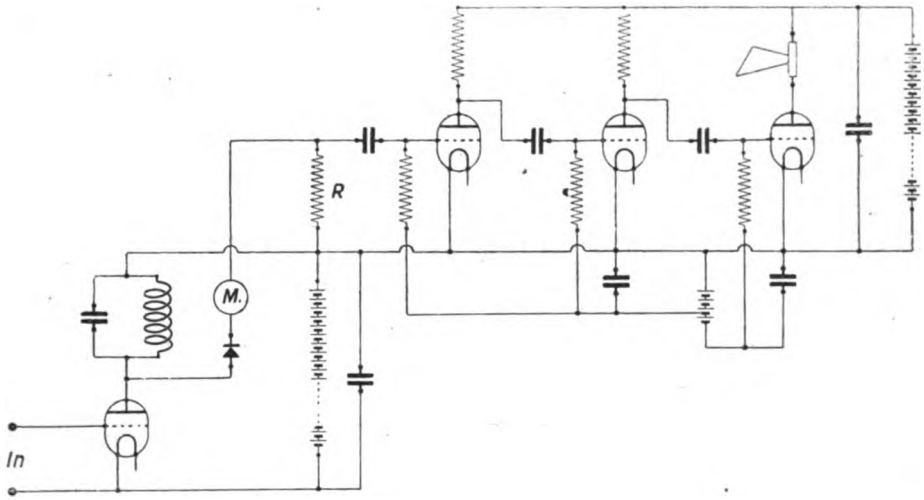

Fig. 2.

The receiving apparatus was installed at Watford, which is some twenty miles NNW of London, and the first observations were made on the Bournemouth station of the British Broadcasting Company, and the harmonic of a neighbouring C.W. station, which happened to be of similar frequency to that of the Bournemouth station, which is of the order of 780kC.

Fig. 3*a* is a diagram of the received current from the Bournemouth station, while Fig. 3*b* is that of the received current from the harmonic of the C.W. station. The form of the curve of Fig. 3*a* is periodic: it shows a regular periodic variation, but the interesting feature is that the received current is substantially constant for a period of thirteen seconds, when it undergoes a sudden diminution lasting for approximately three seconds. This periodic variation was perfectly constant for about an hour, after which the three-second variation which occurred every thirteen seconds became considerably less in magnitude, until the received current became almost constant. It will be noticed that the curve is not complete, the peak values being shown dotted. Owing to the rapidity of the cut-off and the lag in the microammeter, the exact turning point could not be found, although the received music as reproduced by the loud-speaker was just audible throughout the whole cycle. During the intervals marked *X* and *Y* on the current curve, that is, where the rate of change of current with respect to time is high, very clearly defined night distortion was present, but over the sections marked *A* the music was perfectly pure. The advantages to be gained by amplifying the received current and reproducing it by a loud-speaker are obvious, as the curve shown in Fig. 3*a* of course does not give any indication of night distortion. By this method it is possible to observe the relation between night distortion and received current.

While dealing with the subject of acoustic observations, the amateur experimenter should be careful not to record false observations by depending only upon audible

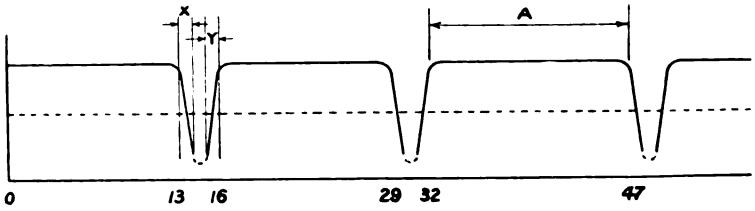

Fig. 3*a*.

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signal strength. While it cannot be denied that the volume of sound from a loud-speaker or telephone receiver is proportional to the received current, it is of little use to endeavour to plot a curve of received current by estimating the variation in volume of the sound. Although the human ear is very sensitive to variation of intensity in sound, the accuracy of the observations depend upon the rate of change of sound with time, and can only be relied upon when this exceeds a certain value. I have found that it is possible for the received current to increase by 100 per cent. over a long period without any perceptible change being noticed by the ear, while an almost instantaneous increase of some 15 or 20 per cent. can be immediately detected by the ear. There is little to be said with regard to curve 3b, which shows that the received current is practically constant.

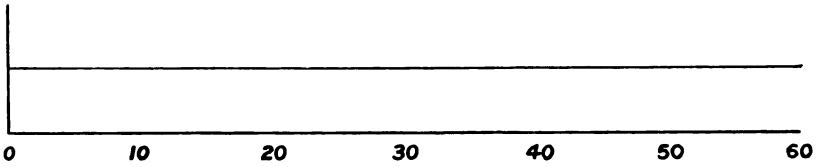

Fig. 3*b*.

Fig. 4 is a rough map which shows the relative position of the two transmitting stations with respect to the receiver. They actually subtend an angle of 15°, and the C.W. station is only 25 miles nearer the receiver. Before commenting upon these results some brief details of another set of observations will be given.

These observations were made chiefly on the Birmingham, Manchester and Glasgow stations of the British Broadcasting Company. The most important of these was the Birmingham station, the frequency of which is not far from 600kC. The received speech and music from the Glasgow and Manchester stations were quite normal both with regard to quality and strength. The reception of the Birmingham station was extremely peculiar. In the first place, the average strength was about a quarter normal, and the general nature of the reception was very similiar to that of a transatlantic broadcasting station. It was subject to fluctuating, but more or less clearly defined periodic fading of considerable magnitude. Unfortunately the recording device was not in operation, and it was therefore impossible to take an actual curve. A more peculiar feature of the reception, however, was the extraordinary night distortion which existed throughout the whole transmission. The observation was made for about an hour only, that is, until the station closed down, and it was only with the greatest difficulty that the identity of the station could be established, as the announcer's remarks were almost completely unintelligible. In fact, it was thought for some little while that it was not a British station which was being received. Both the Manchester and the Glasgow stations have been associated with the reception of the Birmingham station because they lie on a line nearest to that passing through the Birmingham station and the point of reception. However, a number of other stations, both British and Continental, were quickly received, or in other words reception was noted from stations in entirely different directions. In no case could any perceptible fading, or the slightest trace of night distortion, be observed; several of the Continental stations being particularly pure. Fig. 5 is a rough map which shows the directions of the various stations.

The details of these observations may at first sight appear rather peculiar, but an attempt will be made to examine them a little more definitely with the idea of determining whether or not there is really anything strange or abnormal.

Several general theories have been put forward to account for the phenomenon of fading, the most popular of which, I believe, is that reflection takes place from the Heaviside layer, which gives rise to plural path transmission. In other words, it is assumed, for example, that a signal may be received direct from the transmitting station, and also by reflection from the Heaviside layer. Optical interference effects would then occur, which, it is suggested, would explain

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many of the observed effects. Of course there is no reason to assume that only plane reflection takes place, because since we are dealing with a three dimensional medium, something like refraction may also be expected to occur.

If we examine the effects observed in connection with Fig. 5 in the light of this theory alone, it seems that they are really not wholly explained. I think it will be agreed that the results obtained point very strongly to extremely local influence. We find, for example, that reception from Glasgow, that is along the line *GR*, is perfect. A similar result is obtained from Manchester along the line *MR*, which is inclined to the line *GR* at an angle of about 3 degrees. Reception from Cardiff, which is nearly at right angles to the previous direction, is quite normal, as is also the reception from several of the Continental stations. When we turn through only about 15 degrees to Birmingham, we at once find very strong fading and night distortion. An important point to note is that Birmingham is less than one hundred miles away, while Glasgow, for example, is some three hundred miles distant. Apparently the converse of what would be expected is taking place, because the nearer the station the more acute the angle of incidence and the less would be the interference expected. Even if it is agreed that the conditions which bring about the particular fading and distortion observed are extremely localised we have yet to determine the nature of these conditions.

Another suggestion which has been put forward as accounting in part for many of the observed periodic fading effects of short duration, is that the intensity of the received energy is determined by varying local absorption. In other words, it is suggested that the absorption along the given signal path may be determined by purely local conditions, which give rise to varying amounts of absorption. If this is the case, many of the records of signal intensity show that this varying absorption may, or may not, be rhythmic. In the case of the Birmingham reception in this particular instance the signal intensity was very erratic, whereas in the case of the Bournemouth station the swinging was decidedly periodic. It seems probable that this absorption would be due to local ionisation in the atmosphere. Pickard in America, I believe, has suggested that the absorption might be due to formation of banks of ionised particles which might drift about in cloud-like masses. If we assume therefore that these form something similar to the well-known diffraction grating and drift about according to local wind currents, it seems quite likely that the effects which are described in these notes would be more easily explained.

Turning again to Fig. 3*a*, which is the receiving diagram for the Bournemouth station, it will be obvious that the expression for the curve can be resolved by a harmonic analysis into expressions which would represent the movement of one or more banks of ionised particles. For example, it is quite possible that the variation observed on the Bournemouth station could be caused by two "gratings" moving at different rates or in different directions with respect to each other.

It will be remembered that these observations were made on a semi-directional system, a large external loop being employed, as this had been set up for some other experiments. If interference effects were caused by a diffraction grating it seems possible that there might be a change in direction of wave front which would obviously affect a directional aerial system, and influence still further the variation in the received current.

If we assume that the effects are due to local absorption, we can gauge roughly the extent of the localisation by reference to Figs. 4 and 5. Referring first to Fig. 4, the lines *BR* and *CR*, which represent the signal path from the broadcasting and C.W. stations respectively, subtend an angle of about 15 degrees. Along the path *BR* we

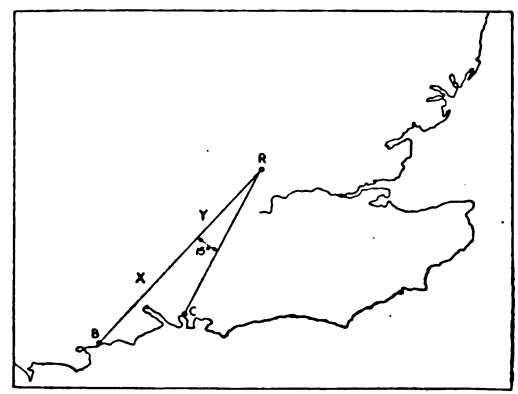

Fig. 4.

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find fading and distortion, while pure reception is obtained along *CR*. As the lines converge at *R* at a comparatively small angle, we are justified in assuming that the two

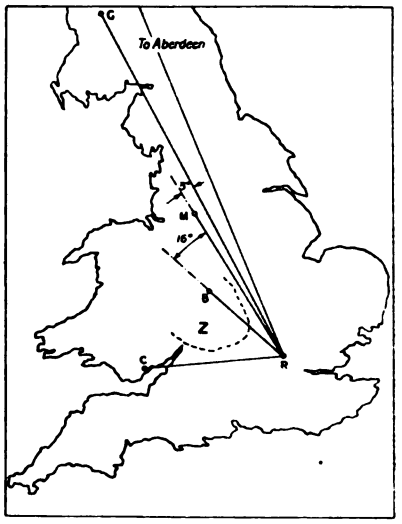
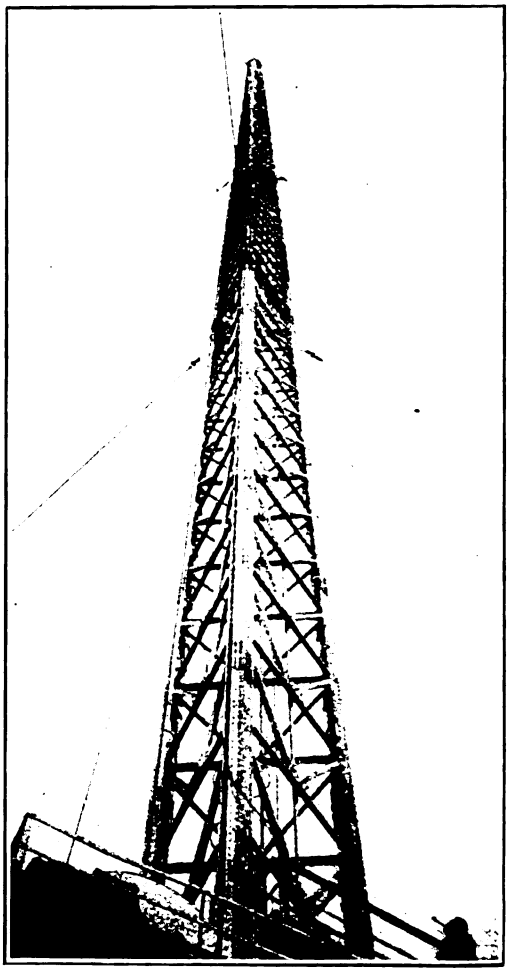


Fig. 5.

lines are common for all practical purposes for some appreciable distance from *R*. Similar reasoning holds good in the case of Fig. 5 with the lines *GR* and *MR*; and to a less extent with *MR* and *BR*. It seems highly probable that in the case of Fig. 4 the disturbing conditions occur in the region marked *X*, although they might equally well exist between *X* and *Y*. In the case of Fig. 5 it would appear that the influencing conditions exist within the region *Z*. Whether we are justified in assuming that the fading and distortion is due entirely to local absorption effects, or not, it is impossible to tell from the existing data. There is no reason, however, why varying absorption should not occur and at the same time be preceded or followed by reflection or refraction from the Heaviside layer. However, I think it will be agreed that the foregoing experiments do lend support to the varying local absorption theory, but of course it would be totally unscientific to suggest that they form anything approaching conclusive proof.



An unusual view of one of the eight giant masts at the new Rugby station. Each of these is 200 feet high and stayed by 15 insulated guys.

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Long-Distance Work.

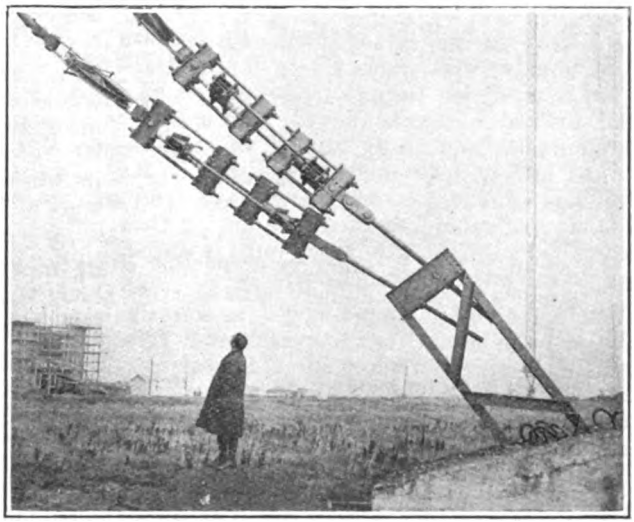
By Hugh N. Ryan (5BV). **[R545·0092**

IT is extremely satisfactory to find that, even so late in the year, our work is proceeding with only little more difficulty than during the winter. It is interesting to note in this connection, too, that last year no British signals were heard in America after 2nd June, while two-way working ceased some time before that date. This year two-way working is still conducted with ease in the middle of June, and bids fair to continue right through the summer.

The factor which has brought about this change is, of course, the use of the shorter waves, notably those around 40 metres. American 90-metre signals can still be heard fairly often, but they are not at all reliable, and the Americans apparently can no longer hear us on that wave. It would appear that we have at last found, in the 40-metre region, the ideal wave-length for purely DX work.

In the past we have found every drop in wave-length attended by better DX results, but this improvement appears to cease somewhere around 40 metres. The waves around 20 metres will evidently travel over great distances, but are somewhat uncertain and less successful over shorter distances. Their most valuable property is their usefulness in daylight, which unfortunately is absent at night. The 40-metre waves, on the other hand, while at their best at night, appear also to travel quite well by day, even in the summer. It seems likely that in the winter trans-atlantic, and possibly trans-world, work will be possible day and night on 40 metres, or thereabouts.

With our present limited knowledge of waves of 20 metres and less, it is somewhat early to prophesy, but I think one may venture the opinion that general, reliable DX work will in future be conducted day and night, all the year round, on about 40 metres, while some wave, or waves, around 20 metres will be used for special purposes. Waves below 20 metres may, on investigation, prove useful, but it is impossible to say what we shall discover there.



One of the stay anchors for the masts at Hillmerton.

Although, as I have said, conditions still allow of our work continuing unabated, the summer weather naturally exerts a retarding force on the operator, even if not on his signals. Hence the amount of work wanes month by month, but a surprising number of stations are still in regular operation, and at least one new country has arrived "on the air." A station signing BG1 has for

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some time been working in Iceland, using the intermediate "Ic." The first British station to work him was 5TZ, of the Isle of Wight, who did so as long ago as April. As far as I know, no other British station has established contact, although BG1 has heard a number of us, and is himself to be heard fairly often. He works on the 90-metre band, with an A.C. note.

Last month I said that 5LF's outward voyage to America (as 6YM) was somewhat disappointing from our end. The reason was that he had unavoidably to abandon his 20-metre and 90-metre schedules and work almost entirely on 45 metres. As a result his signals were often coming in at great strength on 45 metres while many stations were calling him on 90.

I discovered this myself during his homeward voyage, and worked him for several nights, when his signals were excellent. 2KF worked him continuously throughout the double voyage on 45 metres, while 2KZ worked him with 90-metre telephony, 6YM replying on the shorter wave. 5TZ and 2GO, among others, worked him during the outward voyage, the latter using only 3½ watts when 6YM was 1 100 miles out.

Another amateur at sea is F. H. Schnell (u. 1 MO-1 XW and traffic manager of the A.R.R.L.), who is aboard the U.S. warship *Seattle* in the Pacific. During his voyage from San Francisco to Hawaii he worked England (2KF), Australia (2DS) and New Zealand (2AC) as well as many Americans. 5NN and 2FU also report hearing him in London. At Hawaii, Schnell was joined by another well-known American amateur, 6TS. They are using the call sign NRRL on 20, 30, 40, 50 and 80 metres.

By the time this appears in print, a third amateur-bearing ship will have sailed. The Macmillan Expedition ship *Bowdoin*, so famous last year as WNP with Donald Mix as operator, is sailing again this year with John L. Reinartz (1XAM) aboard. We in Europe hope to keep in touch with him as well as the Americans this year.

Few London stations are working regularly now. 5NN has received a confirmed report of his 20-metre signals in Melbourne on 26th April, this establishing him as the first British station heard in Australia on the very short waves.

6LJ has at last taken a rest from the intensive reception for which he is famous, but has nevertheless compiled a good log of stations heard on 20 metres, including u. 6AWT and Argentine CB8.

5AX has moved from Walton to Wallingford, and his station there is already "reaching out" on low power. 6UV is now firmly established on 45 metres, on which wave he has worked nearly every American district, and is heard in America in daylight.

5BV is working seldom, but when he does, he uses a pure D.C. note—sometimes. 5TZ has been struggling with a Master Oscillator, which now, I think, he has mastered. 2KK (Staffs) is still carrying on good receiving work, and will shortly be transmitting.

6JV has been experimenting extensively with various receiving circuits (in the course of which experiments he has worked most European countries), and avows his lack of faith in superheterodynes. I hope he will dislike them less some day. He has worked telephony to Holland with 7 watts.

6YR has worked nearly all Europe with an input of the order of three watts, and has been heard in America on the same power. As a "stunt" he has worked over 22 miles on less than a thousandth of this power.

Before concluding, I should like to mention an interesting organisation which has recently been formed. A number of non-transmitting members of the Cambridge Radio Society, feeling that they did not "get a look in" where DX was concerned, have formed an "experimenters' section" for the purpose of co-operating with transmitting men and furnishing them with reports when required.

This seems to me an excellent idea. Real experimenters (as distinct from purely "distance-hams") often do require reports based on careful and systematic observations. This experimenters' section aims at furnishing such reports to pre-arranged schedules, and attracting other interested amateurs and BCL's into a similar service.

The idea is not yet in full swing, but should be so early next winter. I commend it to transmitting experimenters.

Please let me have reports for the next survey by 10th July.

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For the Esperantists.

Abstracts of Articles in E.W. & W.E., June, 1925.

Resumaro de Artikoloj en E.W. & W.E.

Junio, 1925. [R800

A GLIMPSE AT ESPERANTO.

The Alphabet.

A B C Ĉ D E F G Ĝ H Ĥ I J Ĵ K L M N O P R S Ŝ T U Ŭ V Z.

No Q, W, X, or Y.

Pronunciation.

The Vowels :	**A**	**E**	**I**	**O**	**U**
	bah	there	pier	pore	poor

The **Consonants** sound as in English, except **C** like **ts** in **bits**, *e.g.*, **caro** like *tsaro*; **acido** like ah-tsee'-doh. **Ĉ** like **ch** in **church**. **G** like **g** in **go**. **Ĝ** like **g** in **gem**. **J** like **y** in **yes**, *e.g.*, **jaro** like *yaro*; **bojo** like *boyo*. **Ĵ** like **z** in **azure**. **S** like **s** in **so**. **Ŝ** like **sh** in **show**. **Ĥ** (guttural, very seldom used) like **ch** in **loch**.

AJ, OJ, as in **my boy**. **EJ,** as in **obey**. **UJ,** as in **hallelujah**. **U** is the Esperanto **W**, as in **well, how**; **AŬ** as **ow** in **cow**. **EŬ,** as in **they were**.

Accent always on the second last syllable. Phonetic spelling.
-O is the ending of the **NOUN**. **ADJECTIVES** end in **-A**.
Nouns and Adjectives form the **PLURAL** by adding **-J**.

The simple **VERB** endings :—

Infinitive.	Present.	Past.	Future.	Conditional.	Imperative.
I	**AS**	**IS**	**OS**	**US**	**U**

N marks the **ACCUSATIVE** (direct object). **ADVERBS** end in **E**.

NO IRREGULARITIES. NO EXCEPTIONS.

ANTEN-AGORDILA DESEGNADO.

W. B. Medlam, B.Sc., A.M.I.E.E., kaj
U. A. Oschwald, B.A.,

[R141

UNUA parto de interesa artikolo pritraktanta la plej bonajn proporciojn de antenagordaj induktanco kaj kapacito, post sufiĉa enkalkulo pri la antenaj konstantoj kaj la ŝarĝo alportita de la detektoro.

Nombro da cirkvitoj estas analizitaj teorie, kaj la rezultoj de eksperimentoj montritaj konfirme.

Oni diskutas tri specialajn ekzemplojn, nome: (I) la antena cirkvito senŝarĝita, (II) la efekto de ŝarĝa rezistanco, kaj (III) la efekto de paralela kapacito.

La aŭtoroj montras, ke nur tre malofte ŝajne sin pravigas la paralela agorda kondensatoro.

Rilate al la efekto de ŝarĝa rezistanco de

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kristalo, oni faris nombron da eksperimentoj ĉe kristalcirkvitoj, kun agordo per seria kondensatoro. Oni konektis mikrometron serie kun la kristalo, kaj aranĝis komutatoron, tiel ke oni povu legi la kristalan kurenton kun la bornoj de la 4000-omaj telefoniloj kunligitaj. Oni mezuris la tension trans la antenagorda induktanco per termiona voltmetro. La variadon de kristala kurento rilate al la induktanco oni montras per du grafikaĵoj; ĉe unu oni ricevis la kurvojn mallongigante la cirkviton de la telefoniloj, kaj ĉe alia per la telefoniloj serie kun la kristalo. Oni provis diversspecojn de kristaloj. Oni ankaŭ provis la efikon de valva detektoro.

Por resumi, oni povas konstati, ke la antenagorda kondensatoro estas ordinare malhelpo. En okazo kiam estas ŝarĝo (ekzemple, detektoro) ĉe la cirkvito, ekzistas klare difinita plej bona valoro de la antenagorda induktanco, pligrandiĝanta kun la rezistanco de la ŝarĝo. Aparte ĉe kristaloj, ĉi tiu "plej bona" valoro de induktanco ne sufiĉas, por ke oni povu agordi ĝis la ondolongo bezonita ĉe ordinaraj antenoj. En tia okazo, estus plej bone pligrandigi la kapaciton de la anteno mem kiom eble, kaj se tio ne sufiĉos, pligrandigi la induktancon, prefere ol uzi paralelan kondensatoron. Se oni faros tion, estos avantaĝo konekti la kristalon trans parto nur de la induktanco.

LA PERFEKTA APARATO. [R342·4

Refleksaj Cirkvitoj.

Serio de artikoloj, kies celo ĝis nun estas klarigi kelkajn el la ĉefaj principoj de detektado kaj alt- kaj malalt-frekvenca amplifado. La nuna artikolo pritraktas refleksajn cirkvitojn. Al du Germanoj apartenas la kredito pro la elpenso pri la unua refleksa cirkvito kiun ili patentigis en la jaro 1913a. Estas interese noti, ke nur negravaj plibonigaĵoj estas faritaj ĉe tiu cirkvito eĉ ĝis la nuna tago. En Britujo s-ro. Voight faris multon por disvolvigi kaj popularigi la cirkviton.

La aŭtoro emfaze kritikas la ideon, erare esprimitan diversloke, ke ĝi estas "fantazia" cirkvito, kaj ke ĝi estas senutila por "DX" komunikado, aŭ por brodkastado, k.t.p.

La aŭtoro procedas, pere de du diagramoj, montri kiel facile ortodoksa altfrekvenca transformatore kuplita amplifikatoro kun nedifinita detektoro povas esti konvertita al refleksa cirkvito nur per malkonekto de ĉiu bateria fadeno kaj enmeto de malaltfrekvenca komponaĵo, dum la antaŭaj "elmetaj" bornoj estas rekondukitaj pere de transformatoro al la unua krado.

Li tiam diskutas la diversajn ŝanĝojn produktitajn de la konvertigo, kaj je altfrekvenca kaj malaltfrekvenca amplifado, kaj klarigas kiel oni povas forigi la malavantaĝojn. Li aludas la popularan eraron pri "trivalvaj refleksaj" cirkvitoj, kiuj ordinare konsistas nur el detektoro, unu altfrekvenca kaj malaltfrekvenca duala valvo, kaj unu altfrekvenca valvo; tio estas, "unu-valva refleksilo kun detektoro kun unu altfrekvenca." Vera "3-valva refleksilo," t.e., aparato kun 6 ŝtupoj de amplifado, 3 altfrekvencaj kaj 3 malaltfrekvencaj, estas tute alia afero.

Tre grava punkto estas la ebleco de interago interne de la valvo inter la altfrekvenca kaj malaltfrekvenca komponaĵoj. Li pruvas, ke eĉ malgranda aŭ modera kurbiĝo de la valva karakterizo, kvankam nesufiĉa por produkti rimarkeblan malaltfrekvencan distordon pro sia primaria efekto, povas tamen malstabiligi refleksan cirkviton pro moduliĝo de la altfrekvenca kurento kaŭzita per troŝarĝo ĉe la valvo. La leciono, kiun oni povas lerni per ĉi tio, estas uzi nur bonajn valvojn, kaj ne troŝarĝi ilin.

Unu grava limiĝo ĉe la refleksilo, kiu, tamen, havas grandan avantaĝon por la brodkasta aŭskultanto, estas la fakto, ke ĝi ne estas taŭga cirkvito por mem-heterodina ricevo de kontinuaj ondoj. Se oni pligrandigas la reakcion ĝis osciligo, la aparato ordinare ululas laŭtege. Tial, ĝi estas beno ĉe la brodkasta aŭskultanto—aŭ plivere al lia najboro—ĉar ĝi signifas, ke li ne povas senintence oscili sen tuja ekscio.

Unu granda virto de la refleksilo estas, ke ĝi estas aparte taŭga por kristala ricevado; la kristalo donas plibonajn rezultojn je telefonio, kaj havas utilan efikon por stabiligi la altfrekvencan amplifikatoron.

PROVOJ PRI IZOLECO.

DE H. C. STEPHENSON. [R280·0122

Priskribo pri simpla metodo por provi proksimume per orfolia elektroskopo la izolajn ecojn de diversaj materialoj uzataj ĉe senfadena laborado. Kvankam ne preciza instrumento, ĉi tiu simpla speco de elektroskopo, konstruita je malmulta kosto, povas diferencigi inter bonaj, malbonaj kaj nebonaj izolatoroj.

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La elektroskopo konsistas el du malgrandaj strioj de orfolio, kiuj pendas vertikale de fino de bone izolita metala vergo. La foliojn ĉirkaŭas metala skatoleto, por ŝirmi ilin kontraŭ aerblovetoj. Se oni frotetas je maniko pecon de ebonito, kaj per ĝi tuŝas la metalan vergon, la folioj elektriĝas kaj malkonverĝas ĝis ili formiĝas inversita V. Ili restas tiel ĝis la ŝarĝo elfluas tra la izolatoro. Tiumaniere oni povas havigi proksimuman indikon pri la izola eco de materialo se oni tenos unu finon per la fingroj kaj metos la alian finon kontraŭ la metalan vergon, al kiu la folioj estas ligitaj. Ĉe bona konduktoro, la folioj kolapsas tuj; tamen, ĉe bona izolatoro oni povas rimarki apenaŭ ian efikon. La tempo kiu pasas, ĝis la folioj kolapsas, montras proksimume la izolan econ de la materialo provita.

Nombro da eksperimentoj montris surprizajn rezultojn. Oni unue provis diversajn fragmentojn de ebonito, polurita kaj nepolurita. La folioj falis treege malrapide, dum pli ol 30 sekundoj. Sekvis provoj ĉe tri specoj de valvingoj—hejmefarita el ebonito, kaj mulditaj specoj kun kaj sen flanĝo. La speco hejmefarita donis la plej bonan rezulton, la lasta speco la plej malbonan. Oni ankaŭ laŭvice provis, kun diversaj rezultoj, bobeningon, varieblan kaj fiksan kondensatorojn, valvojn, kaj kradelfluan rezistancon.

Oni alvenis al la konkludo, ke, aŭ la materialo uzita por la kondensatoraj kovriloj, valvaj izolatoroj, valvingoj, k.t.p., ne estas sufiĉe bona kiel izolatoro, aŭ altgrada ebonito por paneloj kaj aliaj komponaĵoj ne estas absolute necesa.

La artikolo finiĝas per priskribo pri konstruo de elektroskopo, por tiuj, kiuj deziras fari similajn eksperimentojn.

KOMUNIKADO JE ONDLONGOJ NEORDINARE UZATAJ. [R800·650

Lekcio je la Radio-Societo de Granda Britujo, de S-ro. G. G. Blake, M.I.E.E., A. Inst.P., je la 22a Aprilo, 1925a.

La parolanto diris, ke lia lekcio estos mallonga historio de eksperimentoj faritaj pri telegrafio kaj telefonio je ondlongoj eteraj krom tiuj eltrovitaj de Hertz, kun nombro da montraĵoj kaj lumbildoj por ilustri la lekcion.

Oni nuntempe konas 53 oktavojn en la etera spektro, sed per niaj okuloj estas videbla nur unu oktavo. Inter la oktavoj, kiuj troviĝas en la spektro, estas la X-radioj, lumo, mallumo, varmo, Hertzaj ondoj, kaj senfadenaj ondoj.

Pro manko de tempo, la lekciisto decidis pritrakti nur infraruĝajn radiojn, videblan lumon, kaj ultraviolajn radiojn. Li estis desegninta aparaton, kiu montras, ke elektra sparko povas esti la fonto de ultraviolaj radiadoj, la tuto de la videbla spektro, malhelaj varmecaj ondoj, kaj Hertzaj ondoj. Li faris demonstracion pri tiuj ondlongoj, unuope kaj samtempe.

Kondensatora sparko estas riĉa je mallongaj ultraviolaj ondoj, sed malriĉa je similaj longaj radiadoj. Karbona arko estas ĝuste mala; tungstena arko riĉa je ĉiu ondlongo; kvarca hidrarga vaporlampo tre riĉa je ultraviolaj radiadoj.

La ekzisto de ultraviolaj radioj en lumo de karbona arko estis montrita per vitraĵa filtrilo "Chance" a, kaj la fluoresko de "Willemite" (la mineralaĵo en kiu troviĝas zinko). Oni ankaŭ demonstraciis per zinka sulfido, baria platino-cianido, urania vitraĵo, kandelo, butero, k.t.p.

Poste oni montris per lumbildoj kelkajn fotografaĵojn faritajn (1) per nefiltrita lumo de tungstena arko, (2) en tute malluma ĉambro sole per la nevideblaj ultraviolaj radioj, (3) per ultraviolaj radiadoj sole el hidrarga vaporlampo. Pluan fotografaĵon oni montris, kun ĉiuj fluoreskaj objektoj forprenitaj for de la grupo.

La lekciisto diris, ke dum la milito oni sukcese uzis ultraviolajn radiadojn por signalado, kaj por helpi al ŝipoj en eskorto vojaĝi kune laŭ siaj relativaj pozicioj. Pere de hidrarga arko, kiel sendilo, entenita en tubo de "Chance" a vitraĵo—kiu emisiis nur ultraviolajn radiojn—estis eble, fokusante la radiojn ĉe skreno de baria platino-cianido, vidi la fluoreskon tiel naskitan je distanco de kvar mejloj. Aliajn eksperimentojn antaŭ kaj dum la milito li priskribis, montrantajn kiel oni uzis la ultraviolajn radiojn, inter ili la elsendo de sonoj.

La lekciisto poste diskutis la signaladon per blanka lumo, kiu konsistas el sep koloroj, ĉiu reprezentanta malsaman ondlongon.

Jam en la dek-unua jarcento oni utiligis en Alĝerio la heliografion, aŭ la metodon de signalado per la sunradioj. Multaj urboj interkomunikadis per la sunradioj reflektitaj de speguloj konstruitaj sur la supraĵoj de altaj turoj. En la sama lando lastatempe

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francaj inĝenieroj sukcesis signali trans distanco de 170 mejloj, kaj en California, Usono, oni atingis 190 mejlojn.

Selenio estis poste pritraktita. Frue en la 19a jarcento, oni montris, ke selenio povas konduki elektron plibone kiam ĝi estas hele lumigita, ol kiam ŝirmita for de la lumo. Kelkaj aliaj substancoj, kiel ekzemple, natura antimona sulfido, kupra oksido, k.t.p., estas ankaŭ sensitivaj je lumo.

En la jaro 1878a, Bell kaj Tainter montris, ke luma radio estas modulebla per la sonondoj el homa voĉo, kun la helpo de selenia ĉelo. Oni nomis la instrumenton uzitan, la Fotofono. La modulo, tamen, estis tre nebona. Oni faris multajn eksperimentojn per la Fotofono, uzante korkon, lignopecojn, fluidaĵojn, kaj gasojn,—eĉ cigarfumo povas produkti sonojn.

La lekicisto montris cirkviton, elpensitan de si, en kiu selenia ĉelo reguligas la kradon de oscila valvo. Oni povas uzi ĉi tiun cirkviton (a) por funkciigi relajon por kabla telegrafio, (b) por indiki la transiron de stelo trans la vidkampon de teleskopo, (c) sur ŝipo, kiam proksima je lumturo, por fari laŭtan signalon kiam la lumtura radio transpasas la vidkampon de la ĉelo, (d) por fotometraj celoj, normigo de kandelpotenco, (e) por komparo kaj mezuro de kvantoj aŭ radiadoj de radiumo, k.c., (f) la travidebleco de objekto je lumo, (g) la denseco de korpoj de diversaj pacientoj rilate al la X-radioj, (h) kiel nevidebla sentinelo por militŝipaj, armeaj, kaj policaj celoj, (i) malproksima reguligo de aerŝipoj; kaj por multaj aliaj aferoj.

Post kelkaj rimarkigoj pri la uzo de infraruĝaj radioj, la lekciisto finis sian paroladon.

Sekvis diskutado, en kiu partoprenis la fama sciencisto, D-ro. E. E. Fournier d'Albe.

DIREKTEMECOJ DE RICEV-ANTENOJ.

R. L. Smith-Rose, Ph.D., M.Sc., kaj R. H. Barfield, M.Sc. [R115

Priskribas kelkajn eksperimentojn, per kiuj oni havigis difinitajn ekvaciojn por determini la rilatojn inter la orientado de la ricevanteno kaj la rezultanta signalforteco.

Marconi kaj aliaj eltrovis, ke la plej simpla speco de direktita anteno, nome, la inversita "L" anteno, estas plej efika, kiam ĝia horizontala longo kuŝas sur linio kunliganta sendilon kaj ricevilon, kun sia libera finaĵo montranta *for de* la sendilo; dum ĝi estas malplej efika, kiam ĝia libera finaĵo montras *al* la sendilo.

La aŭtoroj prenis sur sin la taskon esplori, kaj teorie kaj eksperimente, ĝis kiom la direkta efekto estas grava ĉe la ordinaraj specoj de anteno nuntempe uzataj, ekzemple, kiel la simpla brodkasta anteno, sub statoj de mezuroj kaj ondlongoj kiel eble plej diversaj.

La direkta efekto de anteno estas difinebla, kiel la diferenco je la antena kurento ricevita per turno de anteno for de ĝia malplej efektiva ĝis ĝia plej efektiva pozicio. Tiun ĉi kvanton oni esprimas per la meza valoro de la du kurentoj.

Post diskutado pri l'afero laŭ simpla teoria vidpunkto, oni alvenis al la konkludo, ke ne estas eble determini la direktecon de anteno per ĉi tiu metodo, escepte se la aŭtoroj estus pretaj enĵeti sin en komplikitan matematikan analizon de antenkurenta distribuo.

Oni tial decidis determini tion eksperimente, per radiogoniometro, tia kia estas uzata ĉe la Bellini-Tosi sistemo de direktotrovado. Oni treege zorge konstruis du antenojn, identajn rilate al siaj elektraj ecoj.

Oni provis nombron da antenoj de diversaj grandecoj, kaj havigis ĉiuokaze la valoron de la direkta efekto, je ondlongoj inter 365 kaj 7000 metroj. Oni pretigis tabelon montrantan la direktemecon de diversaj antenoj. El la kvin ondlongoj, pri kiuj oni faris provojn, tiu de 750 metroj, kun antena longo de 200 futoj kaj alteco de 10 futoj, montris la plej grandan direktan efekton, 0.60; dum je ondlongo 365 metra, kun anteno 80 futojn longa kaj 20 futojn alta, la plej malgranda efekto estis montrita, 0.23. Kvankam la direkta efekto ĉe la plimallonga ondlongo estas malgranda, ĝi estas prikonsiderinda, kiam estas necese atingi la plej bonan rezulton el la anteno por brodkasta ricevado.

La konkludoj ricevitaj estas, ke la inversita "L" anteno havas direktajn karaterizojn, kaj ke la direkta efekto estas pliganda ĉe mallongaj ondoj ol ĉe longaj, kaj ke ĝi pligrandiĝas laŭ la proporcio longeco/alteco de la anteno.

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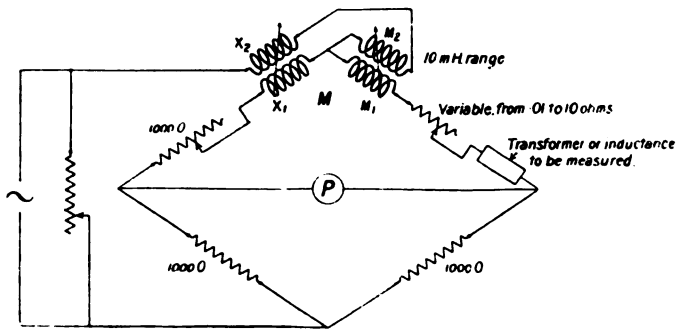
Letters of interest to experimenters are always welcome. In publishing such communications the Editors do not necessarily endorse any technical or general statements which they may contain.

Inductance Measurements.

The Editor, E.W. & W.E.

SIR,—On page 694 of your September, 1924, issue, Mr. Dye gives a diagram of connections used in measuring the inductance of a transformer primary. I do not follow the connections of the



inductometer "M." Should not the two right-hand coils (M_1 and M_2 in my sketch) be the coils of the inductometer proper? If so, are the two left-hand coils (X_1 and X_2 in my sketch) put there to balance that arm of the bridge? Again, if that is so, are the coils X_1 and X_2 variable with regard to each other; if not, and assuming that they are in fixed relation to each other, what was the value of the mutual inductance of the coils X_1 and X_2 used in the author's experiment?

I trust I am not asking too much, but I follow your articles very closely, and would like to thank you for such a thorough journal as E.W. & W.E.

R. K. LLOYD.

Warwick.

The Editor, E.W. & W.E.

SIR,—The inductometer used in these measurements is of the Campbell type as made by the Cambridge Instrument Co. Full particulars of the principles of this inductometer will be found in their catalogue and also in the article in the *Dictionary of Applied Physics*, Vol. II., on "Inductance and its Measurement." The arrangement of the coils is as follows:—

X_1 and M_1 are two equal secondaries on two bobbins. The coils marked X_2 and M_2 are in reality only one coil and induce approximately equal and opposite voltages into X_1 and M_1 respectively. The arrangement saves the necessity of introducing an inductance coil into the left-hand half of the bridge such as would be necessary to balance the secondary of the mutual inductance if the whole of this were in the right half.

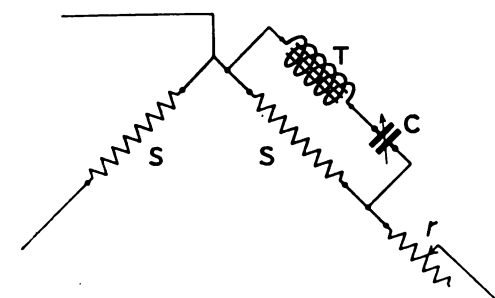
There are thus really two mutuals acting, $-M/2$ on the left-hand half of the bridge and $+M/2$ on the right-hand half.

It is, of course, not necessary to use this type of mutual inductance in the method, which would work just as well if all the mutual were in one half and a balancing coil were used in the other half of the bridge. Again, a variable self-inductance could be used if so desired instead of a mutual inductance. In such a case, however, since we cannot have a negative self-inductance, it would be necessary to transfer the inductance from one arm to the other of the bridge when it was required to make "L" negative.

These measurements of inductance of transformer windings can be made without the aid of any mutual inductance at all by the following modification:—

A variable condenser C is connected in series with the winding T under measurement and the two together are shunted across S. Balance is effected by adjustment of "C" and "r." If R_0 and L_0 are the effective primary inductance of the transformer T as defined in my paper, then

$$R_0 = \frac{S^2}{r} - S, \text{ and } L_0 = \frac{1}{C\omega^2}$$



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The drawback to the method is that frequency must be known to first order accuracy in order to measure L_0 and also that for low frequencies C becomes rather large.

N.P.L., Teddington. D. DYE.

An Unusual Offence.

The Editor, E.W. & W.E.

SIR,—On several occasions during the last few months we have had fixed condensers returned to us for inspection, which have obviously been tampered with, in that the capacity markings have been altered from the original as issued from our factory.

We have been endeavouring to trace the exact sources of supply of these condensers with a view to taking legal action against the firm or firms responsible for tampering with our products, but so far we have been unsuccessful.

The last occasion on which we had a condenser of this nature brought to our notice was in the month of May, this year, when we received one for test which was stamped 0.000 3μF but was obviously not of our marking. On test, this condenser proved to have a capacity of 0.005μF. We therefore wrote to the gentleman who returned the condenser stating the exact circumstances, and sending him a replacement. We asked him if he would kindly give us the name of the firm from whom he purchased the condenser, and we received a reply from him on the 21st May, copy of which we enclose.

We feel that full publicity should be given to all cases of this nature, as it is in the interests of both the radio industry and the buying public to emphasise the necessity for dealing only with firms of repute, and we are sure that you will give us your editorial support in this matter, as this will considerably enhance the value of our "warning" advertisement, which is appearing in your journal.

For and on behalf of
The Dubilier Condenser Co., Ltd.
E. F. BATES.

Victoria Road,
North Acton.

[*Copy.*]

123, Tennyson Road,
Luton.
May 21st, 1925.

DEAR SIRS,—I have yours of the 18th inst., and having enjoyed your courtesy in the receipt of a new 0.000 3mF condenser, am very reluctant to refuse your request that I should furnish you with the name of the dealer who supplied the condenser returned to you for examination.

The man in question is well-known to me and is struggling to make a living in the face of serious ill-health, a circumstance which in any case would make one hesitate to take a step which might result in some injury to him. I have, however, had a talk with the man about the matter and can assure you that any tampering which the condenser in question may have been subjected to was not done by the person of whom I bought it. He was most certainly not the culprit, but rather the victim. Having satisfied myself on this point, will you forgive me for withholding information which would not help you much in reaching the person against whom both you and I have a grievance. I appreciate the seriousness of the offence against you and your products, but any information I could offer in this case would supply no remedy, but might injure an innocent man.

Again thanking you for your goodness and trusting to be excused by you, I beg to remain,

Yours faithfully,
(Sgd.) JOHN BURGOYNE.

The Australian DX Record.

The Editor, E.W. & W.E.

SIR,—With reference to the recent short wave transmissions to Australia, I have just received confirmation by the first mail of the reception of my signals on 18 metres at 4.45 p.m. Melbourne time on the 26th April, strength 6. This you will note precedes by one day Mr. Simmonds' transmission, which was taken as being the first to Australia in daylight, and also it was on a much shorter wave-length, as you will observe. The reception was carried out by the senior engineer on the staff of Amalgamated Wireless, whose name, by the way, is B. Pringle.

In view of the importance of this achievement I am looking to you to give the fullest publicity that you can possibly manage to this announcement, as you will be aware that it was absolutely impossible for me to know before this, as unfortunately Mr. Pringle did not cable me, but simply wrote by the first mail. The time checks exactly with my log and both the letter and my log are open for examination at any time should they be required, in view of the circumstances.

The equipment in use at 5NN was a somewhat unusual circuit, which I shall be pleased to describe should you require any further details at a later date. The valve in use was a Mullard 0.250C, with 200 watts of rectified and smoothed A.C. on the plate; aerial is 37 ft. long, 30 ft. high, counterpoise 40 ft. long, 10 ft. above ground. The aerial, as a matter of fact, is the lead-in of my old 90-metre aerial and is worked on the second harmonic; it lies right in between two houses, and is totally shielded except in one position; the top of the aerial does not come to the top of the house, but about 3 ft. or 4 ft. below. The receiver in use when the signals were picked up in Melbourne was, according to the information received, a low loss two valve tuner, with detector, and one stage of L.F. amplification.

I trust you will give the fullest notice possible to this achievement, since, instead of making me second across it gives me the privilege of being first across on ultra short waves in daylight, and also with the shortest wave-length that has ever been used for long distance transmission in any part of the world.

J. H. D. RIDLEY (5NN).

S. Norwood, S.E.25.

Noises from Electric Light Wires.

The Editor, E.W. & W.E.

SIR,—In houses wired for electric light and heating it is quite possible for the broadcast reception to be marred by a humming noise in the headphones due to induction on the wiring. With crystal sets and a 50-cycle supply this may

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be so loud in comparison with the broadcast signals as to be irritating to the listener, while on a 100-cycle supply, such as exists in certain towns, it becomes a recognised nuisance.

There are various systems of wiring houses for electric light, in some of which the insulated conductors are covered with a metal sheath, while in others there is no such metal coating. As this metal sheathing is connected to earth one would expect houses wired with the metal sheathed wiring systems to be less subject to this interference with wireless signals than those where the wires are not so protected, but to obtain definite data on the point, a simple experiment has been carried out in these laboratories, the results of which may interest your readers.

About 50 yards each of Henley Wiring System twin cable and a similar length of twin insulated cable not metal sheathed were disposed about the laboratory and connected to the two sides of a 2-way switch which enabled one or the other to be connected to a 250 volt 50 cycle supply. The headphones of a crystal set placed within a few feet of the cables gave perfect silence with the Henley cable connected, but a perceptible hum with the unprotected rubber. On connecting a 3-valve amplifier and loud-speaker to the output of the crystal set, the induction from the rubber-covered cable developed into a loud note which would spoil any broadcast programme, while when we switched over to the Henley wiring only the faintest note could be detected, and this was evidently due to other wiring about the laboratory, probably lamp flexibles, as it was present whether the switch was open or closed.

It is evident then that in order to avoid interference with wireless receiving sets a metal-covered house wiring system has considerable advantages over the unprotected rubber-covered wire.

P. DUNSHEATH.

Research Laboratories,
W. T. Henley's Telegraph Works Coy, Ltd.
Gravesend, Kent.

Are Aerials Directional?

The Editor, E.W. & W.E.

SIR,—The conclusions arrived at by R. L. Smith-Rose and R. H. Barfield in their article on "Directional Properties of Receiving Aerials" in your June number is not borne out in practice; and in wireless, theory is sometimes misleading.

The following experiment, carried out in the cold weather by the writer in India, proves that L aerials, consisting of a single horizontal wire, 70 feet in length, with a down lead of 30 feet (total length of aerial 100 feet) are directional.

The receiving station was erected on a lawn in the centre of India, for the purpose of hearing Calcutta broadcasting on 425 metres, at a distance of 650 miles, a 3-valve reflex circuit being used.

Great care was exercised in making a good "earth" at either end of the aerial, the earthing systems being identical. The earth lead was only two feet in length from the set to the surface of the earth, but the earth plate was carried down four feet, and the surrounding ground saturated with water. The earth resistance was approximately 45 ohms, whereas it is believed that it is only 25 ohms in England.

It was found that with the aerial directed with its free end towards Calcutta, the reaction coil had to be placed 50 per cent. closer to the aerial coil than was necessary with the free end of the aerial pointing away from Calcutta.

Similar experiments have been carried out in England by another experimenter, the results proving that aerials are directional.

NORMAN P. ROE.

Hayes,
Middlesex.

The Editor, E.W. & W.E.

SIR,—In reply to Mr. Roe's letter, we have to state that the conclusions reached in our article were obtained from experimental results, and it is therefore not clear to us in what way our conclusions are "not borne out in practice." Mr. Roe has evidently not appreciated that it was shown in our article that the directional properties of a receiving aerial depend upon the specific resistance of the earth at wireless frequencies and not upon the actual resistance of the aerial circuit, which may have any value between wide limits, say, from 0.1 to 100 ohms. It was clearly stated that our results were established for working in this country, where the specific resistance of the earth is known from our own measurements at several places in England. In the absence of any knowledge of the corresponding values for India it is difficult to state exactly what results would be obtained, but there is reason to believe that the results would not differ very markedly in a place where it is possible for vegetation to grow.

We trust that Mr. Roe will not think us disrespectful in saying that before we form definite ideas on the subject we should like to have some more scientific results than those obtainable on a 3-valve reflex receiver, in terms of the closeness of the reaction-coupling.

R. L. SMITH-ROSE.
R. H. BARFIELD.

Directional Wireless Receiving Station,
Langley, Bucks.

Station News.

The Editor, E.W. & W.E.

SIR,—The following are the times of tests I am desirous of making with amateurs of Great Britain:—

Calling: CQ, GO, A4L, Oxenham, Chemist, Capetown, K., and a code for verification. Times: nightly from 20th June until 10th July, 9 p.m. G.M.T., and at 11 p.m. G.M.T. Sundays, 21st and 28th June, and 5th July. Wave-length 85-90 metres.

All reports will be much appreciated and will be QSL'd. I will listen for replies as soon as I have finished transmitting. Power 50 watts, output .9 to 1 amp, Meissner circuit, 4-wire aerial 36 ft. high, 4-wire fan counterpoise.

ROBERT OXENHAM.

136, Long Street,
Capetown, South Africa.

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The Editor, E.W. & W.E.

SIR,—Would you kindly insert a brief note to say that the call sign, G5AX has been allocated to me at the address given below. All QSL cards are answered, and are very welcome.

With every good wish for your excellent paper.

F. WALKER.

Crowmarsh,
Wallingford.

The Editor, E.W. & W.E.

SIR,—This station is now active on 175-185 metres, C.W.; input usually 5 watts. I shall be glad of reports, all of which will be promptly answered. I am anxious to get in touch with someone within a hundred miles who can work me on low power in the afternoon between 1 p.m. and 3 p.m. one or two days a week and shall be glad to hear from any of your readers who can help.

ERNEST H. ROBINSON (5YM).

Langmead,
Pirbright, Surrey.

The Editor, E.W. & W.E.

SIR,—The P.M.G. has authorised me to use, in addition to the 150-200 and 440 wave-bands, the following wave-lengths :—

3.7 to 5 metres and 23 and 45 (both fixed).

I shall be on the air shortly on the 3.7 to 5 metres band and should welcome reports.

ROBERT R. PECORINI.

Fern Villa,
Mortlake, London, S.W.14.

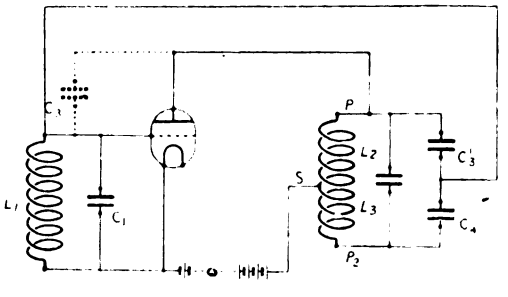

Fig. 1.

The Editor, E.W. & W.E.

SIR,—Please note that the call-sign 2QJ has now been allotted to me.

JOHN F. WARREN.

Pollards,
Gerrards Cross, Bucks.

The Stabilisation of H.F. Amplifiers.

The Editor, E.W. & W.E.

SIR,—A very interesting article in your April issue by O. F. Brown deals with the neutrodyne and bridge methods of stabilising H.F. amplifiers. It appears, however, to have escaped notice that the neutrodyne method itself is a Wheatstone Bridge arrangement.

Fig. 1 below reproduces a neutrodyne circuit such as that shown in Fig. 13*, page 439, of your April issue and Fig. 2 below shows the same circuit

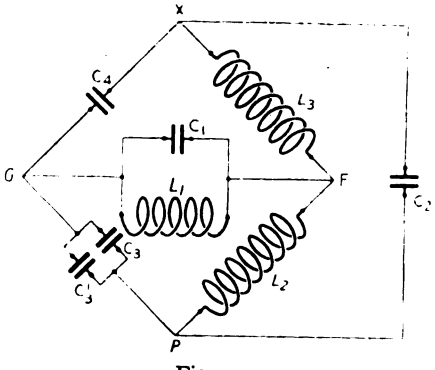

Fig. 2.

redrawn in Wheatstone Bridge form. It is thus seen that the neutrodyne is as much a bridge method as the other "bridge" methods. The only difference is that in the neutrodyne the filament-grid path is a diagonal of the bridge, whereas in the "bridge" method the filament-anode path is a diagonal.

* There appears to be an error in Fig. 13, p. 439, April, as there is no stabilising connection to grid.

The Editor, E.W. & W.E.

SIR,—I agree that the variation of the neutrodyne circuit referred to by your correspondent can be equally well classed as a "bridge" arrangement. I regret the error in Fig. 13 he points out. The connection between the condensers C'_3 and C_4 should be taken to the grid of the valve as shown in the redrawn diagram herewith.

O. F. BROWN.

Wendover,
13, Hampstead Way, N.W.11.

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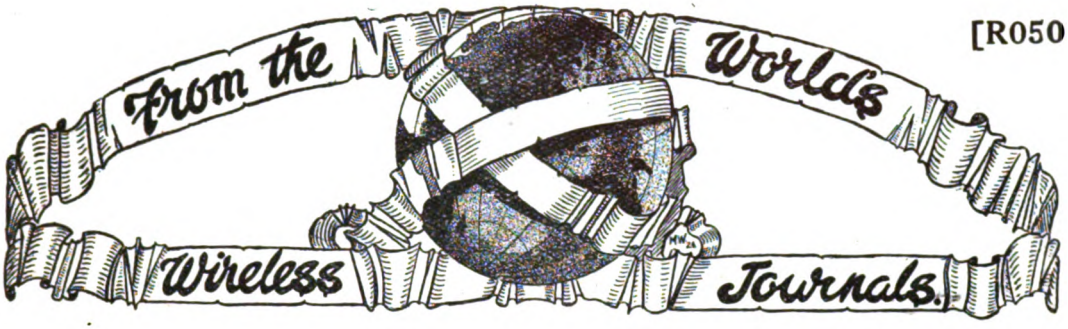
[R050



R100.—GENERAL PRINCIPLES AND THEORY.

R115.—Directional Properties of Receiving Aerials.—R. L. Smith-Rose, M.Sc., Ph.D., and R. H. Barfield, M.Sc., A.C.G.I. (*Exp. W.*, June, 1925).

An account of an investigation made to ascertain the extent to which an ordinary inverted L aerial is directional. Early investigators found that the best results were obtained when the horizontal top of the receiving aerial pointed away from the transmitting station. The effect is particularly pronounced when the length of the aerial is more than ten times its height, and the effect is also more pronounced on short wave-lengths than on long ones. For the average broadcast receiving aerial on 365 metres this directional effect is small; it may be just worth taking into consideration when the very most is to be made of the receiver, but in most cases it is probably outweighed by other considerations.

R141.—Aerial Tuner Design. Part I.—W. B. Medlam, B.Sc., and U. A. Oschwald, B.A. (*Exp. W.*, June, 1925).

The authors analyse mathematically the relation of optimum aerial tuner inductance to the constants of the aerial and the input impedance of the receiver connected to it. They follow up their analysis with some practical data, derived principally from observations made on a local broadcasting station.

R143.—The Optimum Damping in the Auditive Reception of Wireless Telegraphic Signals.—L. B. Turner, M.A., and F. P. Best, M.Sc. (*Journ. I.E.E.*, May, 1925).

A paper read before the Wireless Section of the Institution of Electrical Engineers.

R148.—Geometrische Darstellung der Begriffe Modulation und Schwebung.—Dr. Fritz Fischer (*Telefunken Zeitung*, March, 1925).

An interesting but simple geometrical construction for the waveform of a modulated sine wave is described. As is well known, a pure, simple harmonic motion may be represented by considering a point moving with constant linear velocity round the circumference of a circle whose radius is equal to the maximum amplitude of the oscillation. The radius from the centre of this circle of reference to the point on the circumference has a uniform angular velocity of ω. The projection of this point on any straight line in the plane of the circle executes a simple harmonic motion, which, extended along a linear time axis, gives the familiar sine-wave form. Now suppose the original oscillation has its amplitude modulated in accordance with another harmonic variation of different frequency, the original circle of reference is modified as follows: Make the moving point on the circumference of the original circle the centre of another circle having a radius equal to the modulating amplitude and round which a point is travelling with an angular velocity corresponding to the frequency of modulation. This second point, then, is moving round a circle whose centre is itself moving round a circle, and the projection of this point on a straight line gives the modulated harmonic motion. The latter, when extended along a linear time-axis, shows the modulated wave-form. By means of this construction various interesting cases of modulation (such as over-modulation) may readily be analysed graphically.

R200.—MEASUREMENTS AND STANDARDS.

R251-2.—Etalonnage d'un Système Thermo-Elément-Galvanometre.—M. Abadie (*Onde Elec.*, April, 1925).

Methods of calibrating thermoammeters are described in considerable detail. Errors arising from various causes are dealt with.

R270.—Signal Strength Measurements.—H. J. Round, T. L. Eckersley, K. Tremellen and F. C. Lunnon (*Electn.*, 8th May, 1925).

A report on some experiments made over great distances during 1922 and 1923 by an expedition sent to Australia.

R270.—Eine Anordnung zur Messung der absoluten Empfangs-energie in der drahtlosen Telegraphie.—Dr. L. Bergmann (*Telefunken Zeitung*, March, 1925).

Description of a Telefunken method of absolute signal-strength measurement.

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R300.—APPARATUS AND EQUIPMENT.

R342.4.—Reflex Circuits.—P. K. Turner (*Exp. W.*, June, 1925).

The fundamental essentials of dual amplification circuits are dealt with. The electrical effects of superimposing H.F. and L.F. signals in the same valves are discussed with regard to the considerations of efficient amplification, freedom from distortion and stability from self-oscillation. The writer regards dual-amplification as a logical economy and not as a "freak."

R343.—Nouveau Dispositif de Réglage de la Réaction.—E. Fromy (*Onde Elec.*, April, 1925).

An ingenious method is described of controlling reaction in a regenerative valve receiver. The oscillating circuit has fixed magnetic reaction-coupling, such as the Hartley circuit, and the tendency to oscillate is controlled by varying the effective resistance of the circuit. This is effected by connecting a special condenser across the tuned circuit. It is a double condenser controlled by one knob and so arranged that as the capacity of one half is increased that of the other half is decreased by the same amount. One half is connected straight across the inductance while the other is connected through a fixed damping resistance. The result is that as the knob is turned the total effective capacity remains constant while the effective resistance is continuously and smoothly varied. This controls the tendency of the set to oscillate. Variation of tuning is accomplished by means of a separate, ordinary condenser across the inductance also. A diagram is given showing how the principle may be embodied in a two-valve tuned-anode receiver.

R357.—A New Method of Generating High Frequency Currents.—Prof. G. W. O. Howe (*Electn.*, 8th May, 1925).

An account of some of the recent work carried out in Germany on iron-core frequency raisers. Their action depends essentially upon the distortion of the wave-form of comparatively low-frequency oscillations by the saturation effects in iron-cored coils. This distortion gives rise to harmonics, one of which may be selected and used for radio transmission. Contrary to what would be expected these frequency raisers can be made quite efficient. A generator producing an A.C. output at, say, 5 000 or 10 000 cycles may be connected to a cascade of these multipliers to provide power on a wave-length as low as 600 metres. In view of recent developments the writer considers that the H.F. alternator will still compete with the thermionic valve.

R376.—Some Acoustic Experiments with Telephone Receivers.—Prof. E. Mallet, M.Sc. and G. F. Dutton, Ph.D. (*Journ. I.E.E.*, May, 1925).

A Rayleigh disc was used to find the resonant frequency and decay factor of a telephone receiver under different circumstances as regards diaphragm clamping and air cavity behind the diaphragm. The field of sound in front of a resonator tube and a telephone receiver is investigated by the Rayleigh disc and by a device for measuring sound pressures, and direct measurements are made of the over all acoustical-electrical efficiency of a telephone receiver. It is illuminating to find that this efficiency is of the order of only 0.7 per cent.

R382.1.—A Further Note on Parasitic Losses in Inductance Coils.—Raymond M. Wilmotte, B.A. (*Exp. W.*, June, 1925).

A discussion of the effect of dielectrics in the form of insulation and formers in radio-frequency tuning coils. The general conclusion reached is that the effects of dielectric loss are not very serious as long as reasonably good materials are used.

R400.—SYSTEMS OF WORKING.

470.—Die Entwicklung der Hochfrequenz-telephonie über Hochspannungs-leitungen durch Telefunken.—Dr. W. Moser (*Telefunken Zeitung*, March, 1925).

A short account of the work of the Telefunken Co., of Germany, on the transmission of high-frequency carrier-current telephony along high-tension power lines. It has been found possible to transmit modulated high-frequency currents for a number of miles along such conductors without interfering with their normal functions. The attenuation of signals transmitted in this manner is comparatively small; a case is cited where good communication was effected with a power of only 5 watts over a 100 000-volt line 140 kilometres long. Received currents were found to be a maximum when the wave-length used was some odd fraction ($\frac{1}{3}$, $\frac{1}{5}$, etc.) of the length of the line, *i.e.*, when the line was worked on a harmonic of its own fundamental wave-length. A curve is given which shows how the received current varies with wave-length; the best values for the particular case illustrated appear to lie between 4 and 10 km. Various forms of inductive and capacitative coupling between the signalling apparatus and the power line are indicated, any form of direct conductive connection to the power line being, of course, out of the question. One of the troubles encountered in the use of such lines is the interference from power-leaks at faulty insulators which take the form of aperiodic spark discharges and shock excite the system over the whole radio-frequency spectrum.

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(The following notes are based on information supplied by Mr. Eric Potter, Patent Agent, Lonsdale Chambers, 27, Chancery Lane, W.C.2.)

R008

CONDENSER DIELECTRIC.

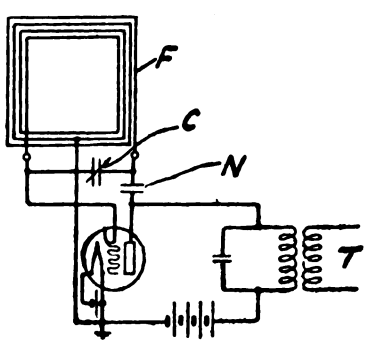
Application date, 28th February, 1924. No. 230,978.)

The Telegraph Condenser Company, Limited, S. G. Brown and W. J. Cole describe in the above British Patent a rather interesting condenser dielectric. Paraffin wax is largely employed as a dielectric in the "paper type" of fixed condenser. There is one disadvantage, namely, that the wax has a negative temperature coefficient in relation to the S.I.C. In other words, as the temperature rises the S.I.C. of the wax falls. This difficulty is overcome by the use of a substance which has a positive temperature co-efficient, and it has been found that the condition of 3 to 5 per cent. of gum dammar to the paraffin wax produces a dielectric which has a substantially constant S.I.C. at all temperatures.

AN INTERESTING FRAME AERIAL CIRCUIT.

(Application date, 29th November, 1923. No. 230,150.)

Those who have experimented with frame aerials will probably have experienced considerable difficulty in preventing self-oscillation owing to the low damping which exists in the grid circuit of the first valve. A rather interesting scheme is described in British Patent No. 230,150 by the Western Electric Company, Limited, and is illustrated by the accompanying diagram. Essentially the invention consists in providing a balancing capacity which tends to neutralise any reaction effects.

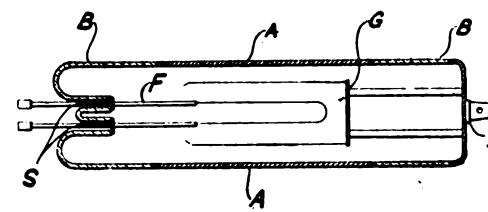


Thus in the accompanying illustration a frame *F* is tuned by a condenser *C*, the grid circuit of the valve being connected between one end of the frame and its mid-point. The other end of the frame is connected to the anode of the valve through a small condenser *N*, which has substantially the same capacity as that which exists between the anode and grid of the valve. The aerial circuit of the valve in this case contains a transformer *T*, but, of course, any other device may be included, or the valve may be caused to function as a rectifier. In practice we find that the scheme works exceedingly well, and should prove of considerable value to experimenters.

A SHORT WAVE POWER VALVE.

(Application date, 20th June, 1923. No. 223,276.)

The construction of a high power valve suitable for operating at exceedingly high frequencies is described by C. S. Franklin in British Patent No. 223,276. In a valve of the usual construction the grid and filament connections are brought out at the same end, and signals at very high frequencies escape through the exceedingly concentrated high tension field acting on the glass



around the grid and filament. As a result of this the voltage has to be reduced, and therefore the valve cannot be worked on full power. This difficulty can be overcome by the following method of construction, illustrated by the accompanying diagram. Essentially the invention consists in sealing the filament in at one end of the valve, and the grid at the other end of the valve. This construction is simplified in the case of an "all metal" type of valve. Thus in the illustration a tubular anode *A* has sealed to it at each end a glass bulb *B*. One of these bulbs carries the filament *F*, which is sealed in at *S*, while the other end carries the grid *G*, sealed in at *X*. Hence it will be seen that the path between the grid and filament seal is exceedingly long, and no intense field can exist between the two.

DIRECTIONAL CONTROL.

(Application date, 12th January, 1924. No. 229,820.)

A method of directing a ship or other moving body in a fog is described in British Patent No. 229,820 by J. D. Roots. The essence of the

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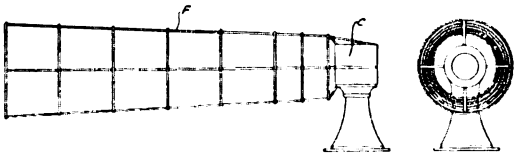
invention lies in providing an ultra short wave transmitter situated at a fixed point and so arranged that it will project a beam along a path

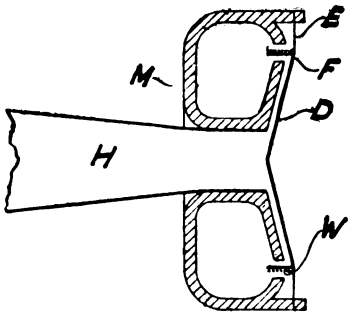


which may vary in altitude and azimuth as desired. The vessel is provided with a receiver which is located in a metal compartment *C* in a conical metal framework *F* of the shape shown in the accompanying illustration. The metal compartment and the conical framework *F* act as a screening device to the beam, unless its axis is coincident with that of the beam. In this case the receiver will be affected, and accordingly the vessel can be steered to the fixed point simply by keeping the axis of the receiving framework and the beam coincident.

A "ROUND" LOUD-SPEAKER.

(*Application date, 29th November, 1923. No. 229,759.*)

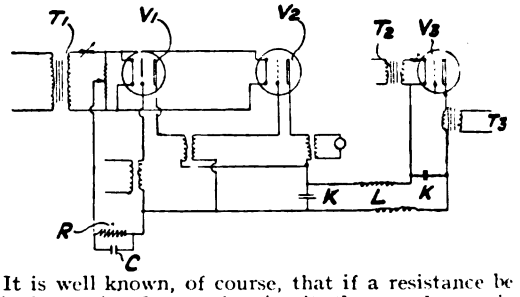
H. J. Round describes in the above British Patent the construction of a loud-speaker which is illustrated in the accompanying diagram. The diaphragm *D*, which may be of conical shape, is supported by a ring of elastic material *E*, which, it is stated, is preferably impervious to air. The diaphragm supports a flange *F*, round which is wound a coil *W*. This flange is arranged so that it lies between the poles of a large magnet *M*, which is intended to be energised by a winding not shown. The magnet in one modification takes the form indicated, and the centre of the diaphragm is here shown in front of the end of a horn *H*, which is attached to the magnet *M*. Thus it will be seen that on applying speech currents to the windings *W* the magnetic field between the magnet and the diaphragm coil will cause the diaphragm to move, and thus produce sound through the horn.



AN A.C. AMPLIFIER.

(*Convention date, France, 10th February, 1923. No. 211,160.*)

Another alternating current amplifier scheme is described in the above British Patent by R. Depriester. The chief sources of trouble which arise when alternating current is used for filament heating are occasioned by the variation of the mean potential of the grid with respect to that of the filament owing to the voltage drop along it and the variation of the temperature of the filament. The inventor states that trouble is also produced by the influence of the external impedance of the grid and filament circuit in relation to the curve of the grid characteristic. An amplification scheme is illustrated in the accompanying diagram which, it is stated, overcomes these difficulties. *V1* and *V2* are two amplifying valves, the filaments of which are fed by a transformer *T1*. *V3* is a rectifier valve, of which the filament is fed by a transformer *T2*, while the transformer *T3* supplies the anode voltage. The valve *V3* functions as an ordinary two-electrode rectifier, and the output passes through the filter circuit *KLK*. The novelty of the invention lies in the method of polarising the grids and also the input transformers.

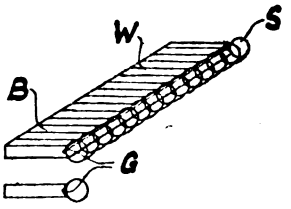


It is well known, of course, that if a resistance be included in the anode circuit the steady anode current flowing through it will cause a potential drop across the ends. This method is employed, and accordingly a resistance *R* is included in the negative lead of the high tension supply. In order to prevent oscillations occurring, the resistance, of course, is shunted with the condenser *C*. The input transformers, it is stated, are wound with very thick wire and have an exceedingly small magnetic leakage. As we have not experimented with the system we cannot say to what degree it is successful, but our own opinion is that for successful A.C. work an equi-potential cathode valve is a simple solution of the problem.

THE GRID OF THE "SHORT PATH" VALVE.

(*Application date, 18th December, 1923. No. 231,225.*)

A rather interesting system of grid construction is described in British Patent No. 231,225 by E. Y. Robinson. When it is desired to produce a valve in which the grid is comparatively near to the other electrodes difficulty has previously been experienced owing to the lack of rigidity. Accordingly the distance between the filament and the anode, for example, is necessarily increased in order to ensure that the grid does not come into contact with either. The object of the invention is to produce a grid which is substantially rigid, and one therefore which can be fitted into a small space without



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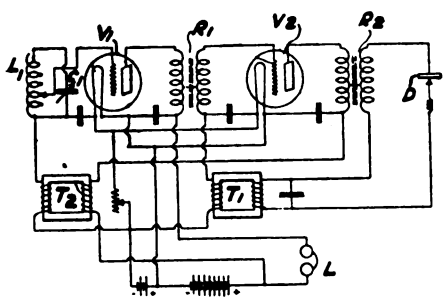
fear of touching the other electrodes. An ordinary spiral grid is employed, but this is attached to a rigid support in the following manner. Referring to the accompanying illustration it will be seen that a spiral grid *S* is made from tungsten or molybdenum wire, and this is fixed to a supporting block *B*. This may be of similar material, and is made rectangular in shape and provided with a groove *G*, in which the grid rests. Each turn of the helix is lashed to the support by means of wire *W*. The grid is almost as rigid as the solid block of metal and accordingly the supporting block *B* can be assembled with the rest of the valve with almost engineering precision. The patent provided for several other modifications and alternative methods of construction of the grid.

THE GRIMES INVERSE REFLEX CIRCUIT.

(*Convention date, U.S.A., 1st December, 1923. No. 225,579.*)

Details of the Grimes inverse reflex circuit are described in British Patent No. 225,579 by the Grimes Radio Engineering Company Incorporated and D. Grimes. In the usual form of reflex circuit a series of valves connected in cascade amplifies signals at radio frequency, after which the radio frequency energy is rectified and the low frequency currents are subsequently amplified by the valves in the same order. According to this

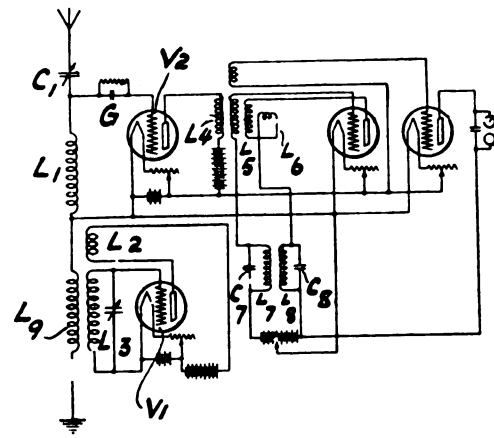


invention, after the signals are detected the low frequency currents are amplified by the series of valves in inverse order. It is stated that this method tends to reduce the amount of oscillation and to equalise the load on the valves. Thus in the accompanying diagram high frequency energy is applied to the valve *V1* by means of the circuit *L1 C1*. The anode circuit of this valve contains a transformer *R1*, the secondary of which is connected to the input of the valve *V2*. The amplified energy is passed on through the valve *V2* by means of a transformer *R2*, across the secondary of which is a crystal detector *D*. The detector *D* is also in series with the primary of an iron core transformer *T1*, the secondary of which is also included in the grid circuit of the valve *V2*. The valve *V2* therefore acts as the first stage low frequency amplifier. The output circuit of the valve *V2* also contains the primary winding of the transformer *T2*. The secondary of the transformer *T2* is also included in the input circuit of the valve *V1*, which therefore acts as a second stage low frequency amplifier. The anode circuit of the valve *V1*, of course, includes the telephones or loud-speaker *L*.

A SUPERSONIC SUPER-REGENERATIVE RECEIVER.

(*Application date, 9th August, 1924. No. 229,938.*)

A very ingenious system of reception is described by the Westinghouse Electric and Manufacturing Company in the above British Patent. There are two rather serious drawbacks to the use of super-regenerative receivers. In the first place there is liable to be considerable radiation from the aerial system, which will give rise to interference to neighbouring receivers, and secondly they do not operate efficiently with damped waves. Both these defects are obviated by the following method: The received signals are first combined with a local source of oscillation, and the resulting beat frequency of 2,000 or 3,000 metres is rectified in the normal way, as in the usual supersonic receiver. The output of this valve



rectifier is then applied to the super-regenerative amplifier. This output is comparable with a modulated continuous wave, and accordingly operates the super-regenerative part of the receiver with the usual efficiency. Thus referring to the accompanying illustration it will be seen that the aerial circuit is tuned by a condenser *C1* and inductance *L1* to the incoming spark frequency. A valve *V1* produces oscillation by virtue of a coupling between the two coils *L2 L3*, and these oscillations are transferred to the aerial circuit by means of a coupling circuit *L9*, which also forms part of the aerial circuit. The valve *V2* rectifies these beats by means of a grid condenser and leak *G*. The anode circuit of the valve contains an inductance *L4* which applies the beats to the super-regenerative system. This consists of the usual two valve arrangement. The ordinary regenerative coils are shown at *L5* and *L6* respectively, while the quenching frequency oscillator consists of the tuned circuits *L7 C7*, *L8 C8*, the usual batteries, telephones, etc. being shown in the usual way. We should imagine that this arrangement would be highly efficient, and should prove of great value to experimenters who are troubled with the radiation problem. The possibility of radiation from the local oscillator, however, must not be overlooked, but in any case this is not likely to be nearly so strong as that obtained from the normal super-regenerative amplifier.

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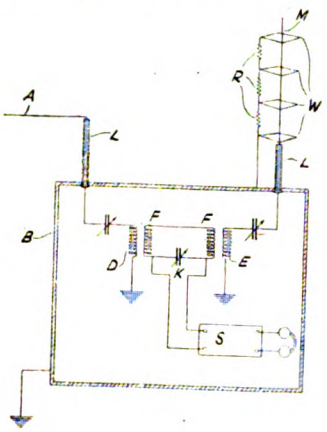
AN ATMOSPHERIC ELIMINATOR.

(*Convention date, U.S.A. 17th August*, 1923. *No.* 220,660.)

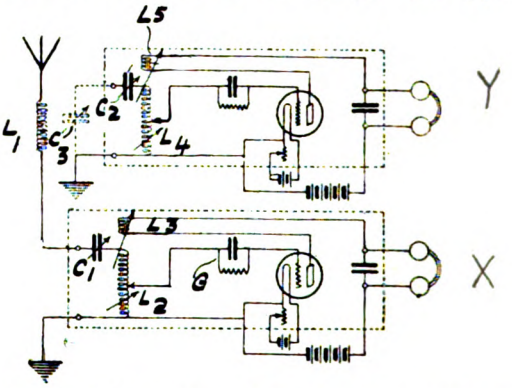
A rather interesting system of interference elimination is described in British Patent No. 220,660 by Marconi's Wireless Telegraph Company, Limited, and J. Weinberger. The system employs two aerials. It is known that a low horizontal aerial, with its vertical down-lead shielded, will respond only to electric fields, while the ordinary type of vertical aerial responds both to magnetic and electric fields. In an ordinary received wave the magnetic and electric fields are equal in magnitude, but in the case of a stray the electric field changes very rapidly, and the magnitude is dependent upon the rate of change, hence the magnetic field may be regarded as being exactly 90 degrees out of phase with the electric field producing it. In other words, the fields of a stray are those of a local stationary field while the fields due to a signal are those of a travelling wave. In this case two currents are introduced in the same circuit by action of the electric and magnetic fields of a stray respectively and neutralise each other, thereby eliminating the stray, while the electric field of the signal is detected. Thus, in the accompanying illustration, the aerial *A* has its down-lead shielded by a lead-in conduit *L*. The second aerial *M* is for the purpose of collecting magnetic fields, and consists of a vertical aerial surrounded by a Faraday cage. This consists of squares of wire *W*, arranged at intervals of a foot along the aerial, and connected together periodically by resistances *R* to earth. This prevents electric fields reaching the aerial, but magnetic fields pass through it readily. The entire receiver is contained within a shielded building *B* which is earthed. The receiver functions in the following manner: In the aerial *A* the electric fields of both signals and strays cause currents to flow through the coil *D*. The magnetic field in the coil due to the signal is 90 degrees out of phase with the electric field, while the magnetic field in the coil *D* is 90 degrees out of phase with the electric field of the stray. In the aerial *M* the magnetic fields of the signal and stray also cause currents to flow through the coil *E*. The magnetic field of the coil *E* due to the signal magnetic field is 180 degrees out of phase with the latter, and therefore 90 degrees out of phase with the magnetic field simultaneously produced in the coil *D*. The current in the coil *E* due to the magnetic fields of strays is similarly 180 degrees out of phase with the latter, but in phase with the magnetic field simultaneously produced in the coil *D*. Thus the stray fields balance out in the circuit *FKF*, leaving only signal currents which are passed on to the receiver *S*. Other methods of bringing about the same result can, of course, be employed.



SELECTIVE RECEPTION.

(*Convention date, U.S.A., 24th July*, 1923. *No.* 219,660.)

A rather peculiar method of selective reception is described in the above British Patent by Marconi's Wireless Telegraph Company, Limited, and E. E. Bucher. Briefly the invention consists in providing two regenerative receivers both coupled to the same aerial, the effect of one regenerative receiver being to reduce the resistance of the aerial circuit to such an extent that by coupling the other receiver quite loosely exceptionally loud signals and excellent selectivity are obtained. One method of carrying the invention into effect is shown in the accompanying illustration, in which there are two receivers *X* and *Y*. There is a common aerial circuit *L*1 *C*1 *L*2. The input circuit of the receiver *X* is taken across part of the inductance *L*2, and a regenerative coil *L*3 and grid condenser and leak *G* are provided. A similar receiver is shown at *Y*. The input circuit consists of an inductance *L*4, a capacity *C*2 and another capacity *C*3, the latter being adjusted to be substantially equal to that of the aerial circuit. In operation the receiver *X* is tuned to the desired signal, and the reaction coil is brought nearly to the point of oscillation. A coupling coil *L*1 is shown in the aerial circuit for the purpose of energising the receiver *Y*, but it is stated that it is frequently only necessary to place the receiver *Y* in the vicinity of the aerial lead. The receiver *Y* is now tuned and the required amount of regeneration is introduced by means of the inductance *L*5. According to the specification the operation of the system is due to the lowering of the aerial resistance by virtue of the regenerative action of the first receiver, but it is not quite clear to us why the first receiver *X* need be used. If the action is merely due to the lowering of the aerial resistance by virtue of the regenerative effect of the first receiver, it would seem obvious that the same effect could be obtained merely by introducing the action into the aerial circuit from a separate regenerative valve, without necessitating the trouble of arranging a separate receiver.



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EXPERIMENTAL WIRELESS & The WIRELESS ENGINEER

VOL. II. AUGUST, 1925. No. 23.

Editorial Views.

A Wireless Institution.

IN our correspondence columns this month are letters from Mr. James Nelson, M.I.E.E., and Mr. Y. W. P. Evans, on the subject of a proposed "Institution of Radio Engineers."

That it is eminently desirable that those technically interested in Wireless—in fact the readers of E.W. & W.E.—should have some such institution nobody will deny. But the question instantly arises as to whether a new body is necessary for the purpose, or whether, on the other hand, they are catered for already, or could be catered for, by existing bodies.

One's thoughts turn naturally to the R.S.G.B. At present, undoubtedly, this is rather a social, semi-technical, and administrative body for the general amateur. We gather that it proposes to retain this position, and has no objection to the foundation of another institution being established for the exchange of technical knowledge.

There are also various other associations of a general wireless interest, but none of these are technical or official bodies.

Lastly, what of the Institution of Electrical Engineers? Here, according to the claims of some of its members who have written published comment on the new suggestion, may be found all that the wireless engineer requires in the way of technical brotherhood.

Unfortunately, as things are at present, this view is hardly justified by facts. True, the I.E.E. has a Wireless Section; but it is open to any member of the Institution, and therefore may contain many members with no qualifications whatever as *wireless* engineers; while at the same time a real highly-skilled wireless engineer, unless he has considerable professional experience of heavy electrical engineering, cannot get in!

The I.E.E. has not yet learned that a wireless engineer needs at once more and less experience than an electrical engineer pure and simple: more knowledge of high frequency technique, and less of some branches of electrical engineering with which he is not directly concerned.

Obviously, the ideal solution would be to have a Wireless Institute under the patronage of the I.E.E., covered (if possible) by its charter and affiliated to it, while having its own qualifications for entry, its own proceedings, and its own distinguishing initials as a mark of membership.

But unfortunately the I.E.E. cannot move quickly—we believe that its next Council meeting is some months ahead. So that it would appear sound to support the proposed new institution provisionally, on the understanding that if the I.E.E. are prepared to recognise the distinct qualifications of the wireless engineer, and cater for him properly, the new body and the Wireless Section of the I.E.E. should be fused.

The greatest difficulty that we foresee (except possibly opposition from competing

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bodies) is that of membership qualification, as regards the proposed grades of Member and Associate Member. Obviously, examination must be the basis. But there are some men, in established positions, for whom an examination would be an indignity. Yet, among these well-known men there are some who are "whited sepulchres"—who have a reputation unearned and unjustified. Such must always be the case. The only obvious way out of the difficulty is to insist on examination for *all* entrants except those who, after the most searching deliberation, are esteemed worthy of being invited as Fellows.

Lastly, a minor criticism: if this is to be a *British* rather than an international institution, why use the international "Radio" instead of the British "Wireless"? We would sooner see it called the "Institution of Wireless Engineers," or the "Wireless Institution." This will also limit the amount of confusion with the I.R.E. of America.

Poor Henry!

People do some curious things in the matter of names. One need only quote the French popular name for a tuning coil, which began by borrowing "self-inductance" from English and went on to drop the last part, so that a coil is now not only a *bobine d'accord* (which is quite sound) but is often called a "*self*." How this must enrage those Frenchmen who love their language!

Just recently we have come across another curiosity, though this time not a matter of language.

We have been testing a considerable quantity of commercial receiving coils, and find them hardly ever to have the nominal number of turns. Coils marked "25," for example, ranged from 22 to 31. The object is fairly obvious.

The first plug-in coils marketed were quoted by their actual number of turns, and new types are being given enough turns to bring them up to the same inductance value. Thus, in addition to the several existing units of inductance, we have a new one. The *turn*, which is "the inductance possessed by one turn of a typical plug-in receiving coil of 1922."

Was there ever anything more ridiculous? Remember, moreover, that the actual inductance is proportional to something between the turns and the square of the turns, depending on the shape of the coil, so that the new unit tells us very little as to the actual inductance.

No; let us stick to microhenries, and exert all influence on the manufacturers to sell coils by microhenries, with perhaps (for the present) some note as to the equivalent number of turns on a typical coil. What is more important, let us *think* in microhenries. As a start, we give below a table showing approximate average microhenries for typical plug-in coils of the best known sizes.

Turns.	μH.	Turns.	μH.
25	30	300	5 000
35	60	400	9 000
50	130	500	15 000
75	300	600	20 000
100	500	750	32 000
150	1 200	1 000	60 000
200	2 200	1 250	90 000
250	3 500	1 500	135 000

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Filters.

By P. K. Turner. **[R386**

To the best of our knowledge there is no simple and fairly accurate account of filter design available at present, so we have provided what we believe to be one. Practice is given first, theory after.

THERE seems to have been written in this country very little about filters that is at the same time correct and reasonably easy to understand. The following notes may therefore be of interest—the analysis on which they are based is given at the end of the article for the benefit of those serious workers who wish to carry the investigation further.

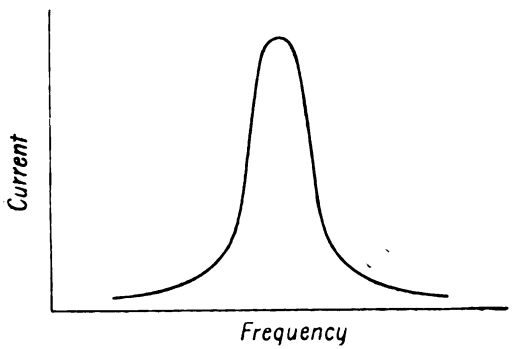

Fig. 1. *A rough idea of the resonance curve of an ordinary tuned circuit.*

First, to clear our ideas, what is a "filter"? Strictly speaking, any circuit which has a selective effect on the currents entering it. A "frequency filter" is one which exercises its effect according to the frequency of the current, and is the only type we are considering.

According to the above definition, any circuit whatever containing inductance and capacity is a filter; but the term has come to be restricted to a particular type. For example, a tuned circuit having a resonance curve of the type in Fig. 1 is not usually called a filter. The word, in modern practice, is used only to denote a circuit in which the object striven for is to give a resonance curve of the type in Fig. 2: a high, even current over some part of the frequency range, and a low, equally even, current over any other part, the dividing line being as abrupt as possible. Such filters are sometimes called "Campbell" filters, and we shall deal only with them. Their uses are very numerous.

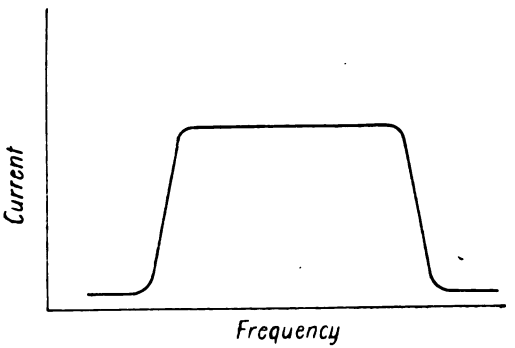

Fig. 2. *By contrast with Fig. 1, this is one sort of curve from a filter such as that in Fig. 3.*

General Ideas.

Now the most general arrangement of such filters is that of Fig. 3, and is seen to be a network of impedances—nature at present unspecified—partly in series with the output circuit and partly across it. It is found to make the calculation much simpler if the two end series impedances are made one-half the value of the rest. The particular filter shown has three stages according to the convention to be adopted in this article, in which the input, but not the output, circuit is regarded as a "stage." In fact, the number of stages equals the number of "Z_2's."

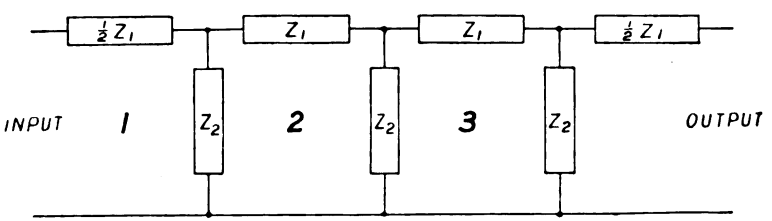

Fig. 3. *The most general type of filter: Z_1 and Z_2 represent impedances of some kind.*

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Such a filter may be made to behave very diversely, by a suitable selection of the values for Z_1 and Z_2. Unless otherwise indicated, we are only considering filters in which all the Z_1's are equal, and also all the Z_2's. Four examples are shown in Fig. 4, together with their ideal frequency-current curves. We say "ideal," because (as we shall show) such curves are actually only got with an infinite number of stages.

The form of the filter usually gives the clue by which we can remember its function. Fig. 4*a*, for example, is a "High Pass" filter. Obviously D.C. (*i.e.*, zero frequency) could not get through it at all. Similarly, for Fig. 4*b*, D.C. wou'd pass easily through the inductances, so we can easily recollect that 4*b* is a "Low Pass" filter; 4*c* and 4*d*, in turn, can be remembered as Band Pass and Band Stop filters by recollecting that the series impedances of 4*c* are "acceptors," which easily pass currents to which they are tuned, whereas the series impedances of 4*d* themselves consist of inductance and capacity in parallel, and therefore form rejectors which stop resonant currents.

We have explained that the frequency curves in Fig. 4 are ideal ones, and could only be given by filters with an infinite number of stages. When the number of stages is finite—say n—the filter is in resonance for $n+1$ distinct frequencies: if n is large enough, these are so close together that they simply give the "flat" top or bottom of the curve a gentle waviness. Note that there is no question of tuning each stage to a different frequency. Each stage *as a unit* is tuned to the same frequency: it is the combination of the stages which gives the different ones. Examples of this will be shown later.

Practical Design.

We can now get down to a consideration of the design of a filter. The questions to be solved are three, being given the frequencies to be passed and those to be stopped: (1) How many stages must be used? (2) What must be the values of Z_1 and Z_2? (3) How are we to design coils and condensers of these values?

The last question will not be considered here, as there is quite a lot of literature on the subject.

Before however going on to give instructions we will, to prevent any chance of confusion, define our terms:—

"Inductance" and "capacity" need no definition. "Reactance" is the opposition to an alternating current offered by an inductance coil or a condenser. It varies with frequency and is measured in ohms.

If the frequency is f, and we define ω as $f \times 2\pi$, and if we call reactance X, then for an inductance

$$X = \omega L \quad .. \quad .. \quad (1)$$

where L is the inductance in henries.

For a condenser,

$$X = -\frac{1}{\omega C} \quad .. \quad .. \quad (2)$$

where C is the capacity in farads. (Note that capacity reactance is negative.)

Impedance is the combined effect of reactance and resistance. It is measured in ohms and called Z, and is got by

$$Z = \sqrt{R^2 + X^2} \quad .. \quad (3)$$

Next, there are two frequent errors in considering filters that might be cleared up.

First, it is common to find the impedance of the filter itself at various frequencies, and consider it as a constant thing in itself. Certainly, it is a "thing-in-itself," but it is not constant; it varies with the impedance of the output load. It is not accurate simply to add the impedance of the unloaded filter to that of the load and expect the sum to be the impedance of the whole circuit.

Second, it seems to be thought that on adding stages to a filter they all behave alike: *e.g.*, that if one stage cuts down a current to 1/10, two stages will cut it to 1/100, three stages to 1/1 000, etc. This again is not accurate; for each stage has a different output load, and, as shown above, this means that each stage behaves differently.

I have, however, found a way of expressing the impedance effects of the load and the filter itself, by the aid of some graphs. These have been worked out for 1-, 2-, and 3-stage filters; and are reproduced herewith.

Let us call Z' the "filter impedance" of the filter, *i.e.*, the *input* volts divided by the *output* current. Z_1 and Z_2 have already been defined; Z_1 is the impedance of the series part of one stage and Z_2 that of the parallel part (see Fig. 3); Z_e is the external or load impedance.

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Now it is possible to find certain quantities, which we are calling A and B, such that, at any frequency,

$$Z' = B\,Z_e + A\,Z_2 \quad .. \quad (4)$$

Obviously the last part gives the impedance on short-circuit, *i.e.*, when $Z_e = 0$.

We give curves for these two quantities, always negative. (Those inclined for mathematics should also note that if account is taken of the *resistance* of the filter components, s will be a complex quantity.) Throughout these notes we are assuming that the resistances in the filter itself are negligible, as is the case in practice except where specially noted otherwise. Thus,

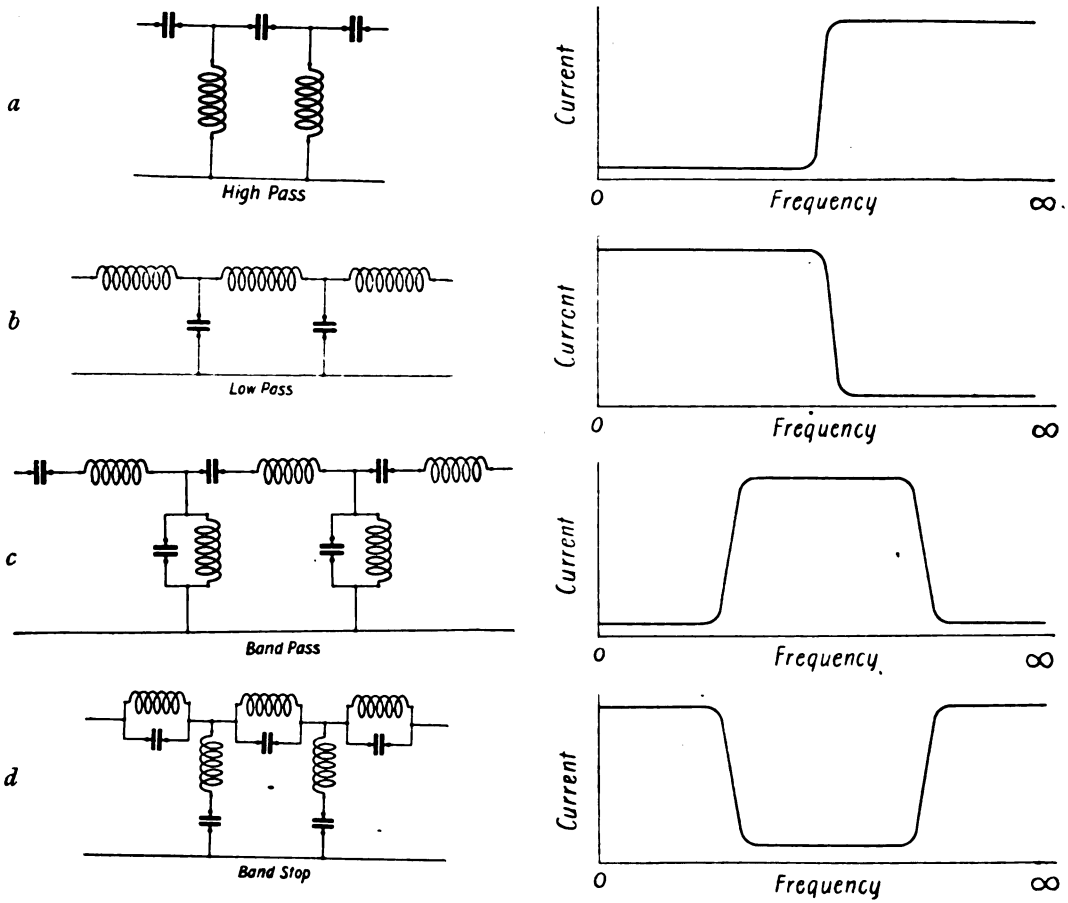

Fig. 4. *The four main types of filter, with their ideal resonance curves.*

A and B, but in order to make them available for various types of filter we have had to express them, not directly in terms of frequency, but in terms of a quantity s, which depends on frequency, and which we will now define :—

$$s = \frac{Z_1}{Z_2} \quad .. \quad .. \quad .. \quad (5)$$

It is to be noted that in every type of filter that we are dealing with here, s is since R is zero, Z_1 and Z_2 reduce to X_1 and X_2 respectively (see equation (3)), and we have

$$s = \frac{X_1}{X_2} \quad .. \quad .. \quad (6)$$

In the case of a *Low Pass filter*, X_1 is due to a coil of inductance L, say, and X_2 due to a condenser C, so

$$s = \frac{\omega L}{-1/\omega C} = -\omega^2 LC \quad .. \quad (7)$$

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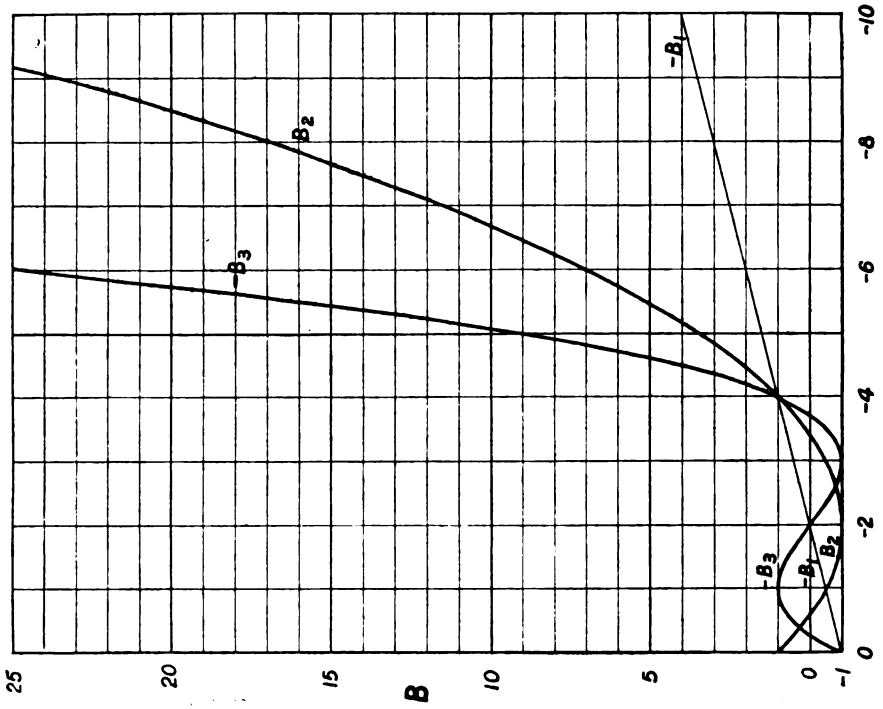

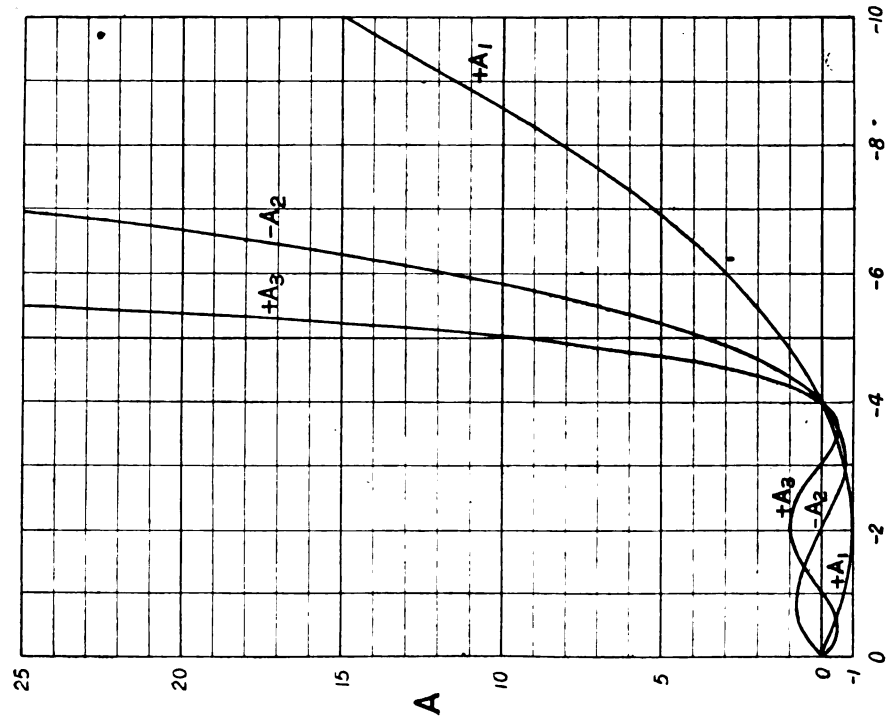

Figs. 5 and 6. *Curves for A and B, the two quantities which enable one to design filters with ease. For explanation see matter.*

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For a *High Pass filter*, X_1 is due to a condenser and X_2 to an inductance, and

$$s = -\frac{1}{\omega^2 LC} \quad .. \quad .. \quad (8)$$

Working out the other two cases, we have:—

Band Pass filter

$$s = -\frac{(1-\omega^2 LC)^2}{\omega^2 LC} \quad .. \quad .. \quad (9)$$

Band Stop filter—

$$s = -\frac{\omega^2 LC}{(1-\omega^2 LC)^2} \quad .. \quad (10)$$

Remembering that, if the natural frequency of a simple circuit containing L and C is f_0, and $\omega_0 = 2\pi f_0$, then

$$\omega_0^2 LC = 1,$$

it will be seen that alternative expressions for s are (putting λ_0 for the wave-length corresponding to f_0),

Low Pass—

$$s = -\left(\frac{\omega}{\omega_0}\right)^2 = -\left(\frac{f}{f_0}\right)^2 = -\left(\frac{\lambda_0}{\lambda}\right)^2$$

High Pass—

$$s = -\left(\frac{\omega_0}{\omega}\right)^2 = -\left(\frac{f_0}{f}\right)^2 = -\left(\frac{\lambda}{\lambda_0}\right)^2$$

Band Pass—

$$s = -\left(\frac{\omega}{\omega_0}\right)^2 = -\left(\frac{f_0}{f} - \frac{f}{f_0}\right)^2 = -\left(\frac{\lambda}{\lambda_0} - \frac{\lambda_0}{\lambda}\right)^2$$

Band Stop—

$$s = \frac{-1}{\left(\frac{\omega_0}{\omega} - \frac{\omega}{\omega_0}\right)^2} = \frac{-1}{\left(\frac{f_0}{f} - \frac{f}{f_0}\right)^2} = \frac{-1}{\left(\frac{\lambda}{\lambda_0} - \frac{\lambda_0}{\lambda}\right)^2}$$

Where, in each case, L and C are the inductance and/or capacity of a single unit, and in the case of band filters it is assumed that the inductances and the capacities in the series units are equal individually to those in the parallel units. The value of s, where this is not the case, is a little more complicated, but can be easily worked out by those interested.

By means of formulæ (7) to (10), or (5) or (6) in more complicated cases, s can be found for a series of values of ω, and hence, by the curve sheets reproduced as Figs. 5 and 6, A and B can be found for all frequencies.

This enables us to find Z', but as a general rule we are not so much interested in Z' as in the ratio Z'/Z_e, for it can easily be shown that this latter is what may be called the "filtering ratio"; the proportion of applied voltage which actually reaches the load. It is easily seen from equation (4) that

$$\frac{Z'}{Z_e} = B + \frac{Z_2}{Z_e} A \quad .. \quad (11)$$

In the case of complicated filters, Z_2/Z_e is a quantity which varies with frequency, and must be worked out in each individual case. But in the case of High Pass and Low Pass filters one can express it quite simply, in cases where Z_e is either a pure inductance or a capacity. We then have the following four values for Z_2/Z_e:—

	Low Pass.	*High Pass.*
$Z_e = \omega L_e$	$\frac{L}{L_e} \cdot \frac{1}{s}$	$\frac{L}{L_e}$
$Z_e = -\frac{I}{\omega C_e}$	$\frac{C_e}{C}$	$\frac{C_e}{C} \cdot \frac{1}{s}$ (12)

We therefore see that Z'/Z_e can for these cases be expressed in terms of B and either A or A/s, and to deal with this latter case, which often arises, we give curves for A/s as well as for A.

Coming now to the curves themselves, Fig. 5 gives values of A for 1-stage, 2-stage, and 3-stage filters. Note that the value for a 2-stage filter is given as negative, in order to avoid doubling the size of the diagram: *e.g.*, A_2 for $s = -6$ has the the value -11.5. Note also that at various values of s between 0 and 4, A falls to zero, which appears to mean that the filter has no impedance. Actually, as we have stated above, we have neglected resistance throughout, so that what this actually means is that there is no *reactance*; the impedance depends only on the ohmic resistance, and in any well-designed filter it will be, not actually zero, but at any rate a minimum. By the same token, a negative value of A means that the *reactance* is negative, *i.e.*, that at that frequency the filter behaves as a condenser. Fig. 6 shows values of B, and the remarks made in connection with Fig. 5 also apply.

In these two figures, however, the necessity of showing what happens when s is greater than -4, *i.e.*, when the filter is "cutting off," has made us show on rather a small scale the effect when the filter is "passing." We therefore show to an enlarged scale in Figs. 7 and 8 values of A and B when s is less than -4. Also, in Figs. 9 and 10, we give two corresponding curves for A/s.

How, then, do we set out to design a

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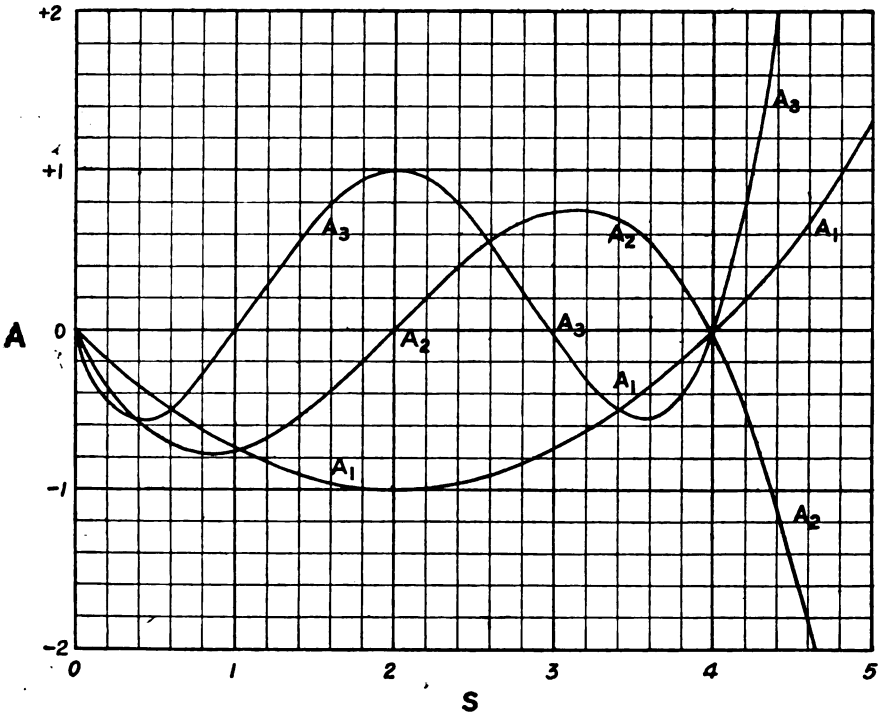

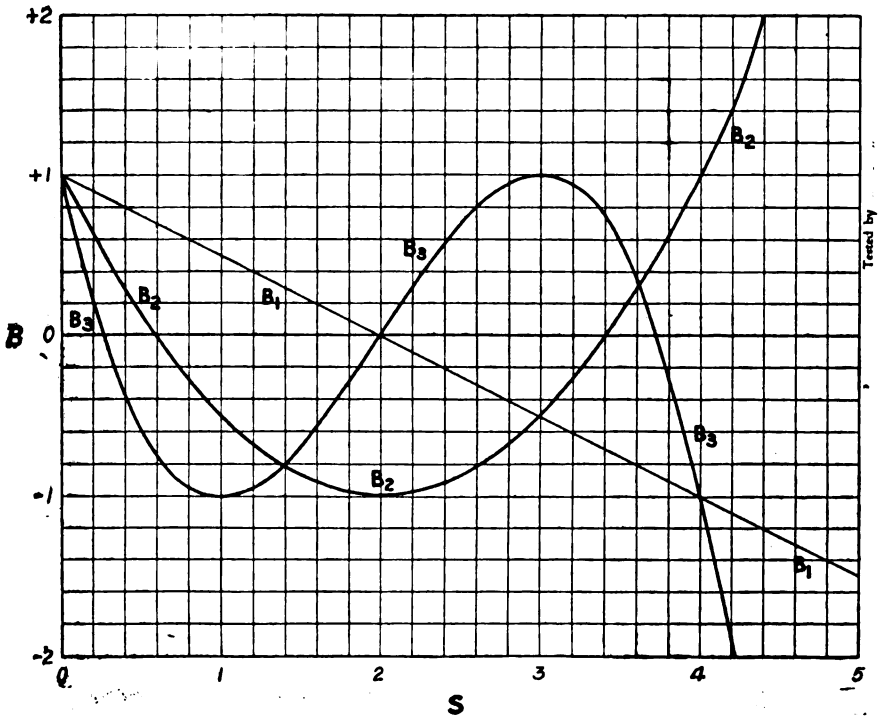

Figs. 7 and 8. *Enlargements of that part of Figs. 5 and 6 dealing with small values of s.*

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filter? We must first know two, or rather three, things: First, the pass frequency range; second, how sharp a "cut off" is required; third, what is the load impedance. Perhaps we can best show by an example. A recent case we had to consider was a special filter for a long-wave amplifier. It had to pass all audio-frequencies, but cut off everything from 30 000 upwards; and the working load was an L.F. transformer. It was, therefore, a Low Pass filter, for which (see equation (7))

$$s = -\omega^2 LC$$

Fig. 5 showed that the critical value of s is -4, and we therefore, as a preliminary, said: "s shall be -4 for f about 20 000, or $\omega = 125\,000$, or, say, $\omega = 120\,000$.

What, then, is Z_e at frequencies of this order? Well, an intervalve transformer consists, really, of a high inductance shunted by a condenser (its own self-capacity). Most transformers resonate at 2 000—3 000 cycles. Above this they act as condensers. At 20 000 cycles practically all the current will flow through the capacity, and so we will neglect everything else and say that Z_e is due to a condenser of .000 1μF.

This leads us to (12), from which

$$\frac{Z_2}{Z_e} = \frac{C_e}{C},$$

and we want to find out what value of C_e/C, used in equation (11), will give us a good high value of Z'/Z_e for frequencies of 30 000 and over, while at the same time keeping this value low for audio-frequencies up to, say, 15 000.

For this purpose we got out, using Figs. 5 and 7 and equation (11), the curves of Figs. 11 to 13, showing Z'/Z_e against s for various values of C_e/C. Remember that we wish to pass 20 000 and stop 30 000. The value of s for the latter is approximately twice that for the former. Also, we naturally want to use as few stages as possible, and we will assume that Z'/Z_e must be *at least* 50 for 30 000 frequency: *i.e.*, only 1/50 of the applied voltage is to get through, as an absolute maximum.

Looking at Fig. 11, we find that with one stage we can just fulfil the requirements by putting $s = -4\frac{3}{4}$ for 20 000 cycles, when we shall have $s = -10$ (about) for 30 000, using $C_e/C = 3$. This, however, means a value of Z'/Z_e of -3 for $s = -2$ (about 12 000 cycles)—the filter will cut off quite a lot of the audio-input for high notes. Further, $C_e/C = 3$ means that the filter condensers must be one-third the load capacity, or .000 03, which will mean very large inductances.

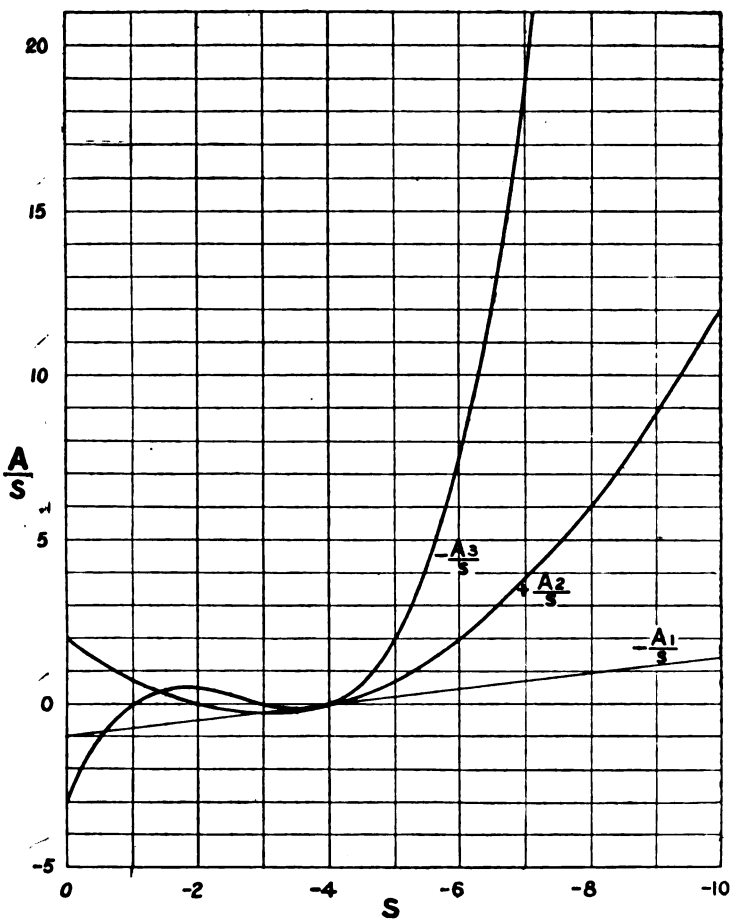

Fig. 9. *A curve for A/s, which is needed in some cases.*

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Comparing Fig. 12, for two stages, we find that for $C_e/C = 1$, with $s = -5$ for 20 000 cycles, we shall get a much higher filtering ratio at 30 000 cycles (over 100) while the largest values of Z'/Z_e for low frequencies are 1.5 at $s = -1\frac{1}{2}$ and 1 at $s = -4$. The former means a 33 per cent. decrease in input at 10 000 cycles. Examination of Fig. 13 shows still higher efficiency, but at the cost of an extra stage. Assume then two stages, $C_e/C = 1$.

This means that the filter condensers must be .0001, as was the load. Also, $s = -\omega^2 LC = -5$ for a frequency of 20 000 (or $\omega = 120\,000$ approximately). Knowing ω and C, we can find L, which comes out at 3.5 henries. Our filter will therefore be as shown in Fig. 14, remembering that the end coils are one-half the centre one.

(N.B.—This condition—that the end units are $\frac{1}{2}Z$—may seem to offer difficulties in band filters, when each unit has both inductance and capacity. The solution is to use half the inductance and double the capacity.)

This completes the design of the filter *as a filter*. True, we have to work out the turns, etc., of the coils; but that is the design of coils, not filters, and (as already stated) will not be treated here.

Recapitulating the design procedure :—

(1) Find out what Z_e is, and decide what sort of filtering ratio (Z'/Z_e) is wanted for the "cut-off" part of the range, and between what frequencies the cut-off is to occur.

(2) This will give the clue to the type of filter. By the use of (11) and (12) draw rough curves of Z'/Z_e against either s or frequency, for various values of Z_2/Z_e.

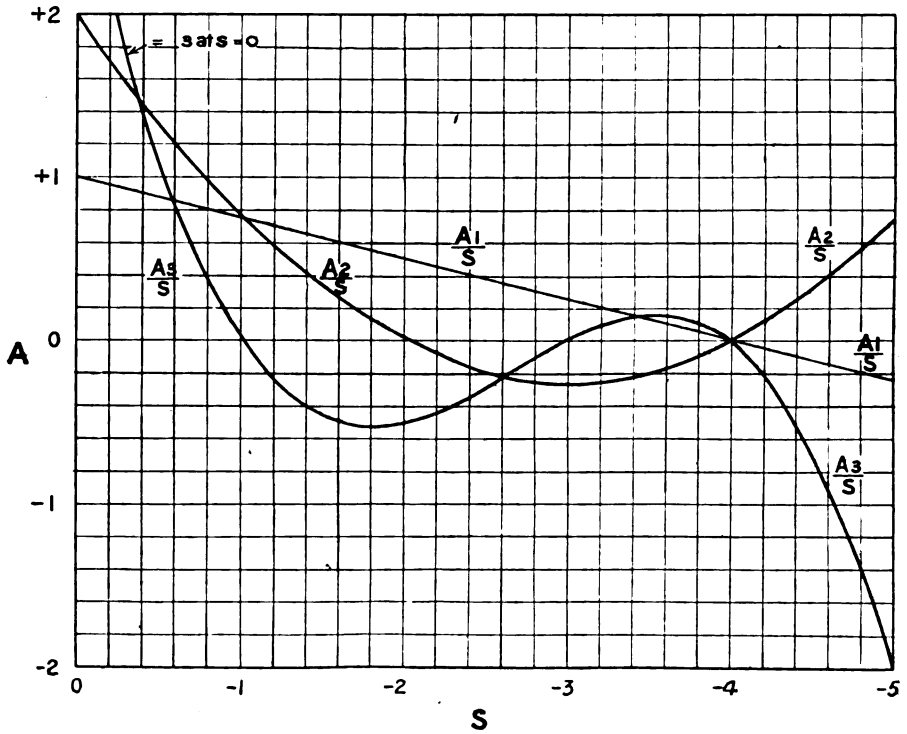

Fig. 10. *The lower part of Fig. 9 enlarged.*

(3) Decide from these the most hopeful curve. High values of Z_2/Z_e give high ratios in the "pass" region, but give a good "cut-off" with few stages. Don't forget that high or low values of Z_2/Z_e may affect the ease of construction of the filter. Individual judgment and "horse sense" must come in here.

(4) Having decided on Z_2/Z_e you can specify the coil or condenser value for Z_2, and from s, ω (or frequency) and Z_2 you can find the coil or condenser value for Z_1.

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Theory.

The analysis is based on a treatment by Cohen, which appeared in the *Journal of the Franklin Institute*, May, 1923, and which had the great advantage of dealing with filters having a finite number of stages.

This treatment, however, did not include any provision for an output load, and was mainly directed towards finding the resonant frequencies. From the present point of view the expression for current (or, alternatively, impedance) at various frequencies is the real desideratum.

As the effect of a finite load shows itself quite early in the analysis, it is considered best to give here the complete calculation, and not merely a supplement. This also enables us to avoid one or two errors in the Cohen analysis as presented.

Regarding now Fig. 15, it is obvious that the E.M.F.s acting in any circuit, say the mth (not an end circuit), fulfil the equation:—

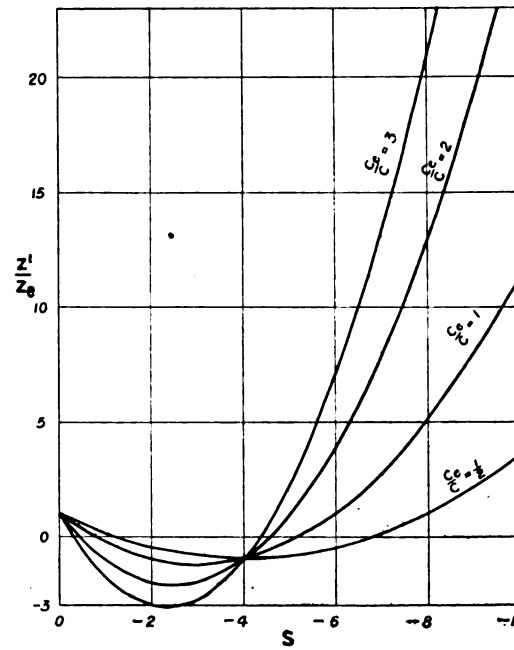
$$(Z_1 + 2Z_2)I_m - Z_2(I_{m+1} + I_{m-1}) = 0 \qquad (13)$$

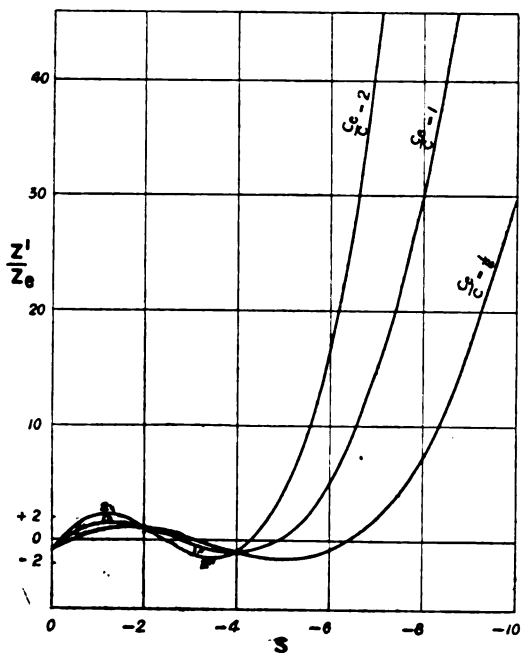
I_m being supposed the current set up by a sinusoidal E.M.F. applied at the input, and Z_1 and Z_2 being impedances of the form $R + jX$.

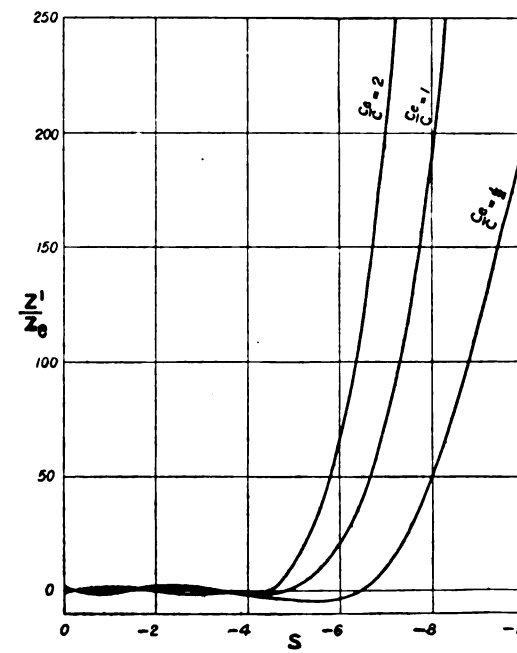
It is easily proved that the solution of (13) is

$$I_m = (-1)^m (A\epsilon^{m\gamma} + B\epsilon^{-m\gamma}) \quad .. \quad .. \quad (14)$$

subject to a condition as to the value of γ.







Figs. 11 to 13. *Three curves showing the performance of the particular filter chosen as an example, and shown in Fig. 14.*

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Substituting from (14) in (13) we have

$$(-1)^m Z_1(A\varepsilon^{m\gamma}+B\varepsilon^{-m\gamma})+Z_2[2(-1)^m(A\varepsilon^{m\gamma}+B\varepsilon^{-m\gamma}) - (-1)^{m+1}(A\varepsilon^{\overline{m+1}\gamma}+B\varepsilon^{-\overline{m+1}\gamma}) - (-1)^{m-1}(A\varepsilon^{\overline{m-1}\gamma}+B\varepsilon^{-\overline{m-1}\gamma})]=0 \quad (15)$$

Collecting terms in the second expression,

$$(-1)^m Z_1(A\varepsilon^{m\gamma}+B\varepsilon^{-m\gamma}) = -(-1)^m Z_2(A\varepsilon^{m\gamma}+B\varepsilon^{-m\gamma})\,(\varepsilon^{\gamma}+\varepsilon^{-\gamma}+2) \quad (16)$$

whence $-Z_1/Z_2 = \varepsilon^{\gamma}+\varepsilon^{-\gamma}+2$,

or $$\varepsilon^{\gamma}+\varepsilon^{-\gamma} = -(2+Z_1/Z_2) \quad .. \quad (17)$$

or, as an alternative expression,

$$ch\,\gamma = -(1+\tfrac{1}{2}\,Z_1/Z_2) \quad .. \quad (18)$$

which is the condition for γ.

To find A and B (these are not, of course, the quantities defined as A and B in the earlier part of this article), we use the conditions in the first and last circuits.

E being the input voltage, we have :—

$$(\tfrac{1}{2}\,Z_1+Z_2)\,I_1 - Z_2 I_2 = E \quad .. \quad (19)$$

Substituting from equations (17) and (14), we find

$$Z_2(\varepsilon^{\gamma}+\varepsilon^{-\gamma})\,(A\varepsilon^{\gamma}+B\varepsilon^{-\gamma}) - 2Z_2(A\varepsilon^{2\gamma}+B\varepsilon^{-2\gamma}) = 2E$$

or, on simplifying,

$$A\varepsilon^{\gamma}-B\varepsilon^{-\gamma} = -\frac{2E}{Z_2(\varepsilon^{\gamma}-\varepsilon^{-\gamma})} \quad .. \quad (20)$$

For the $(n+1)^{th}$ or last circuit,

$$(\tfrac{1}{2}Z_1+Z_2+Z_e)I_{n+1} - Z_2 I_n = 0 \quad .. \quad (21)$$

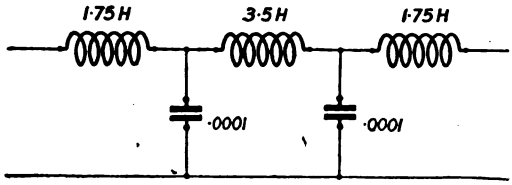

Fig. 14. *The example : a filter to pass freely up to* 20 000 *cycles, and practically stop everything above* 30 000.

or

$$(Z_1+2Z_2)\,I_{n+1} - 2Z_2 I_n = -2Z_e I_{n+1}$$

again substituting from (17) and (14),

$$-(-1)^{n+1}Z_2(\varepsilon^{\gamma}+\varepsilon^{-\gamma})\,(A\varepsilon^{\overline{n+1}\gamma}+B\varepsilon^{-\overline{n+1}\gamma}) - 2Z_2(-1)^n(A\varepsilon^{n\gamma}+B\varepsilon^{-n\gamma}) = -2Z_e(-1)^{n+1}(A\varepsilon^{\overline{n+1}\gamma}+B\varepsilon^{-\overline{n+1}\gamma})$$

dividing by $(-1)^n Z_2$, and simplifying,

$$A\varepsilon^{\overline{n+1}\gamma}(\varepsilon^{\gamma}-\varepsilon^{-\gamma}-2\,Z_e/Z_2) - B\varepsilon^{-\overline{n+1}\gamma}(\varepsilon^{\gamma}-\varepsilon^{-\gamma}+2\,Z_e/Z_2) = 0$$

or

$$B = A\varepsilon^{\overline{2n+2}\gamma}\,\frac{\varepsilon^{\gamma}-\varepsilon^{-\gamma}-2r}{\varepsilon^{\gamma}-\varepsilon^{-\gamma}+2r} \quad .. \quad (22)$$

where $r = Z_e/Z_2$.

Now substituting from (22) in (20),

$$-\frac{2E}{Z_2(\varepsilon^{\gamma}-\varepsilon^{-\gamma})} = A\varepsilon^{\gamma}-B\varepsilon^{-\gamma}$$

$$= A\varepsilon^{\overline{n+1}\gamma}\left(\varepsilon^{-n\gamma}-\varepsilon^{n\gamma}\,\frac{\varepsilon^{\gamma}-\varepsilon^{-\gamma}-2r}{\varepsilon^{\gamma}-\varepsilon^{-\gamma}+2r}\right)$$

$$= A\varepsilon^{\overline{n+1}\gamma}\cdot\frac{-(\varepsilon^{\gamma}-\varepsilon^{-\gamma})(\varepsilon^{n\gamma}-\varepsilon^{-n\gamma})+2r(\varepsilon^{n\gamma}+\varepsilon^{-n\gamma})}{\varepsilon^{\gamma}-\varepsilon^{-\gamma}+2r}$$

or

$$A = \frac{-2E\varepsilon^{-\overline{n+1}\gamma}(\varepsilon^{\gamma}-\varepsilon^{-\gamma}+2r)}{Z_2(\varepsilon^{\gamma}-\varepsilon^{-\gamma})[2r(\varepsilon^{n\gamma}+\varepsilon^{-n\gamma})-(\varepsilon^{\gamma}-\varepsilon^{-\gamma})(\varepsilon^{n\gamma}-\varepsilon^{-n\gamma})]} \quad (23)$$

In terms of hyperbolic functions, this becomes

$$A = \frac{E\,\varepsilon^{-\overline{n+1}\gamma}}{2\,Z_2\,sh\,\gamma}\cdot\frac{sh\,\gamma+r}{sh\,\gamma\,sh\,n\gamma - r\,ch\,n\gamma} \quad (24)$$

and by a simple transformation, using (24) in (22)

$$B = \frac{E\,\varepsilon^{\overline{n+1}\gamma}}{2Z_2\,sh\,\gamma}\cdot\frac{sh\gamma-r}{sh\,\gamma\,sh\,n\gamma - r\,ch\,n\gamma} \quad (25)$$

Finally, substituting these values of A and B in the expression derived from (14) for the current in the load, one sees at a glance from (24) and (25) that the expression simplifies considerably. We have, in fact,

$$I_{n+1} = (-1)^{n+1}\,\frac{E}{Z_2(sh\,\gamma\,sh\,n\gamma - r\,ch\,n\gamma)} \quad (26)$$

If now we define Z' as E/I_{n+1} (input E.M.F. over output current), we have

$$Z' = (-1)^{n+1}(Z_2\,sh\,\gamma\,sh\,n\gamma - Z_e\,ch\,n\gamma) \quad (27)$$

or if we define Z'/Z_e as the "filtering ratio" (ratio of input E.M.F. to the E.M.F. across the load)

$$\frac{Z'}{Z_e} = (-1)^{n+1}\left(\frac{Z_2}{Z_e}sh\gamma\,sh\,n\gamma - ch\,n\gamma\right) \quad (28)$$

As shown in (18) above, γ is defined by

$$ch\,\gamma = -(1+\tfrac{1}{2}\,Z_1/Z_2),$$

and it will be found that in all useful reactive filters, Z_1/Z_2 is essentially negative, so that where $Z_1/Z_2 > 4$ in absolute value, $ch\gamma$ is positive and > 1 as is necessary.

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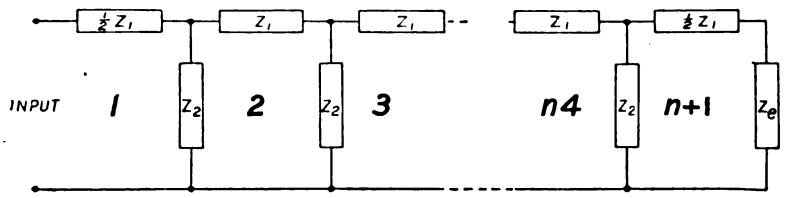
For $Z_1/Z_2 < 4$, $ch\gamma < 1$. To deal with these cases, we have only to postulate $\gamma = j\theta$, whereupon (18) converts to

$$\cos\theta = -\left(1 + \tfrac{1}{2}\frac{Z_1}{Z_2}\right)$$

and (28) becomes

$$\frac{Z'}{Z_e} = -(-1)^{n+1}\left(\frac{Z_2}{Z_e}\sin\theta\sin n\theta + \cos n\theta\right) \quad (29)$$



(28) and (29) can be expressed a little more neatly by changing the exponent of -1 thus :—

$$\frac{Z'}{Z_e} = (-1)^n\left(ch\,n\gamma - \frac{Z_2}{Z_e}sh\,\gamma\,sh\,n\gamma\right)$$

$$= (-1)^n\left(\cos n\theta + \frac{Z_2}{Z_e}\sin\theta\sin n\theta\right) \quad (30)$$

The curves for "A" and "B" in the earlier part of the article are derived from (30) ;

$$\text{"A"} = (-1)^n \sin\theta\sin n\theta$$
$$= -(-1)^n sh\,\gamma\,sh\,n\gamma$$

while

$$\text{"B"} = (-1)^n \cos n\theta$$
$$= (-1)^n ch\,n\gamma$$

Resonances.

If it is desired to get, without actually drawing curves, information as to resonant frequencies, one has only to put $Z' = 0$, when we have

$$Z_e\,ch\,n\gamma = Z_2\,sh\,\gamma\,sh\,n\gamma,$$

or $$-Z_e\cos n\theta = Z_2\sin\theta\sin n\theta \quad .. \quad (31)$$

or $$sh\,\gamma\,th\,n\gamma = Z_e/Z_2$$

$$-\sin\theta\tan n\theta = Z_e/Z_2 \quad .. \quad (32)$$

These equations are easily solved graphically, and will be found as a rule to have $n+1$ solutions.

In the case of a shorted filter ($Z_e = 0$) both equations (32) lead to

$$n\theta = s\pi \quad (s = 0, 1, 2, \ldots . n) \quad .. \quad (33)$$

Under these conditions, equation (18) becomes

$$\cos\frac{s\pi}{n} = -\left(1 + \tfrac{1}{2}\frac{Z_1}{Z_2}\right) \quad .. \quad (34)$$

Where there is any possibility of resonance, Z_1/Z_2 will not be independent of ω : putting $Z_1/Z_2 = f(\omega)$, we have

$$f(\omega) = -2\left(\cos\frac{s\pi}{n} + 1\right) \quad .. \quad (35)$$

and putting $s = 0, 1 \ldots . n$, we have $n+1$ values for $f(\omega)$ from which we can find $n+1$ resonant frequencies.

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A Variable Resistance for Radio Frequencies.

[R248

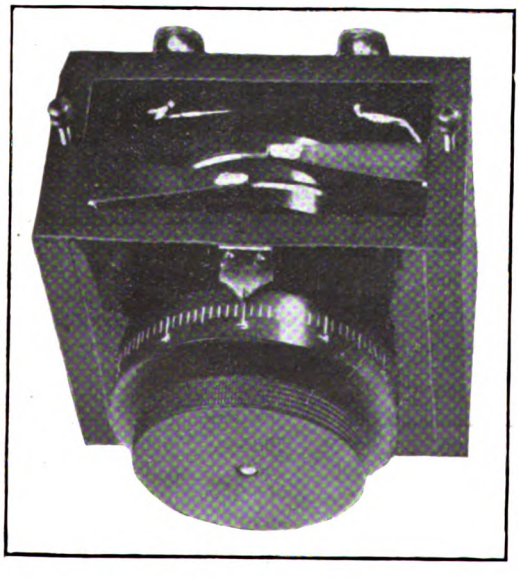
By R. M. Wilmotte, B.A. (of the National Physical Laboratory).

Describing the design and construction of an instrument enabling continuous resistance variations to be made without affecting the shape and reactance of the circuit.

IT is often necessary in measurements at radio frequencies to be able to vary the resistance of a circuit. This is usually done in discontinuous steps by adding short lengths of resistance wire.

The need of being able to vary the resistance continuously to simplify certain measurements became apparent to the writer, and it was with this end in view that a number of designs were tried and tested. In order to fit with resistance boxes available for radio frequencies, which read units up to 10 ohms, it was decided to design a variable resistance reading to just over 1 ohm with a scale divided into hundredths of an ohm using about 25 cms. of wire.

A variable resistance for radio frequencies is required to have the following properties: It must be possible to vary the resistance without altering the shape of the circuit in any way, so that in the usual case, when an E.M.F. is being induced into the circuit in which the measurements are made, the coupling, whether magnetic or capacitative, will remain unaltered. The value of the resistance should be very little affected by frequency, and the reactance of the circuit should not change as the resistance is altered.



A photograph of the actual instrument.

It is not possible to make a resistance absolutely inductionless or without capacity: the terminals alone will always have a capacity of 2 or $3\mu\mu$F. This will alter the effective resistance and self-inductance of the resistance.

Supposing R is the effective resistance, L its self-inductance, and C its effective capacity, then the resistance can be represented to a high degree of approximation by an equivalent circuit having a capacity C shunting the resistance R and the inductance L in series. This circuit can easily be shown to be equivalent to a resistance R_0 in series with a self-inductance L_0 where

$$R_0 = \frac{R}{(1-LC\omega^2)^2+R^2C^2\omega^2}$$

and

$$L_0 = \frac{L(1-LC\omega^2)-R^2C}{(1-LC\omega^2)^2+R^2C^2\omega^2}$$

When L and C are both small these approximate to

$$R_0 = R \text{ and } L_0 = L-R^2C.$$

From this it is seen that in order to keep L_0 small, it is necessary to make L and C as small as possible, while the effective resistance is unaffected so long as L and C are sufficiently small.

The variation of resistance in the design finally adopted is obtained by making part of the wire of copper and the other part of some high resistance wire. The brushes are kept fixed and the wire moved, so that when the pointer is at zero, the wire between the brushes is nearly all copper and when the pointer is at 1 ohm the wire between the brushes is nearly all resistance wire. In this way the shape of the circuit remains absolutely unaltered.

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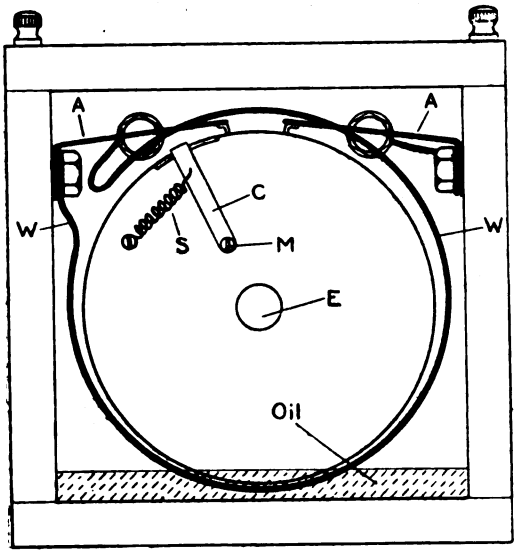
On account of its good surface qualities, nickel wire, which was tested and shown to be non-magnetic, was chosen. No. 20 S.W.G., having 0.8 ohm resistance per metre, was rolled out to a thickness of 0.045 mm. and a width of 2 mm. so as to have a resistance of about 5 ohms per metre. This was necessary on account of the "skin" effect, which would have been very appreciable in the circular wire at high frequencies.

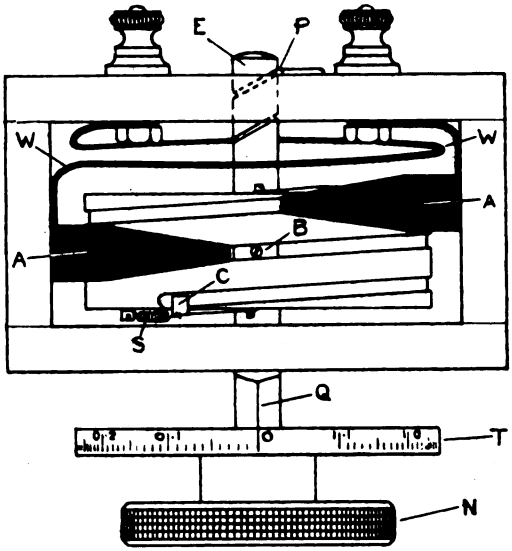
The wire thus rolled out showed no appreciable "skin" effect at a frequency of 1 500 kilocycles per second. Some No. 20 S.W.G. copper wire was similarly rolled to a thickness of 0.042 mm. and a width of 2 mm.

Diagrams of the variable resistance are given in the accompanying figures, which show the instrument in plan, with the top removed and in elevation, with one side removed. The wire is wound round an ebonite drum 7.7 cms. in diameter in which a small rectangular groove 3 mm. in width and 1 mm in depth is cut — making two complete turns of 1 cm. pitch. One turn is of copper and the other of nikelin, soldered at the centre of the groove to a fixed copper strip *B*. The other ends of the wires are soldered on to copper strips *C*, pivoted at *M* and held by springs *S*.

This was found necessary, for in ordinary resistances which are wound on ebonite, trouble often occurs through the expansion of the ebonite with a rise in temperature, which causes the wire to come out of the groove when the ebonite cools. By means of the springs *S* this difficulty is overcome.



ELEVATION WITH SIDE REMOVED.



PLAN WITH TOP REMOVED.

The reason for the big pitch of the groove is to diminish the effective capacity and the proximity effect: that is, the loss due to the eddy currents in the wire produced by the magnetic field of the rest of the wire. This would be produced mainly by the radial component of the magnetic field, owing to the large width of the wire compared to its thickness, and it is the radial component which is most affected by the proximity of the turns.

The brushes *A* are made of phosphor bronze with a small silver contact fitting into the groove. As the handle *N* is turned the ebonite drum advances while the brushes remain in the grooves. This motion is obtained by a pin *P*, which fits in a screw thread cut on the spindle *E* of the drum. On this spindle is fixed another ebonite drum *T*, on which the scale is engraved. This is read by means of a fixed pointer *Q*. The scale moves backwards and forwards with the motion of the drum, so that it is necessary either to have a long pointer or engrave the scale on a helical line.

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In the instrument as described the current makes one complete turn of the drum and resistance has, therefore, quite an appreciable self-inductance. This is counter-balanced by the thick copper wire W, which is fixed, going from one brush, round the drum to the terminal. This wire is always in the circuit, so that the current flows in one direction round the drum and in the other direction along the wire W. The area enclosed by the current is thus very small.

A small layer of transformer oil was put at the bottom to keep the surface of the metal clean. By rotating the handle once the groove becomes filled with oil and good contact is ensured between the brushes and the wire. The whole instrument fits a cubical box of 12 cms. side.

There is, of course, always a resistance in circuit, even when the pointer is at zero. The calibration refers to the difference in resistance and not the actual resistance, this method being the most convenient for the majority of purposes.

The instrument was compared with some No. 37 S.W.G. manganin and showed an error of $\frac{1}{2}$ per cent. at 1 500 kilocycles. The D.C. calibration therefore can be assumed to hold up to that frequency.

After a lapse of two months, the calibration had not altered to within 2×10^{-3} ohms. The instrument has been in constant use and has proved to be reliable, no trouble of any kind having been encountered with the contacts.

A simple application of a variable resistance is in the measurement of effective resistances by the resistance variation method. In this method the current I_1 in a tuned circuit is measured and a resistance r added, reducing the current to I_2. If the current in the circuit does not react on the source and the coupling remains unaltered, the resistance R of the circuit is given by

$$R = \frac{I}{I_1 - I_2} \cdot r$$

When a large number of these measurements have to be taken, they become very tedious. The work is much shortened and the reliability slightly increased if r can be adjusted to make I_1 a simple fraction of I_2.

Thus, if

$$\frac{I_2}{I_1} = \tfrac{1}{2},\ \tfrac{3}{5},\ \tfrac{5}{8},\ \tfrac{2}{3},$$

$$\frac{R}{r} = 1,\ \tfrac{3}{2},\ \tfrac{5}{3},\ 2.$$

This represents the usual range, for the accuracy decreases rapidly for small and large ratios of I_1 to I_2. Curves by which I_2 can be read quickly from I_1 for any of the above ratios are convenient, for it is necessary to take more than one reading to obtain reliable results. By this means the author has been able to reduce the time of taking readings in conjunction with high frequency resistances research by nearly one-half.

The apparatus described herein has been designed and used in connection with work carried out for the Radio Research Board established under the D.S.I.R., and I am indebted to the Committee of the Board on Propagation of Waves and Standards for their helpful criticism.

A Correction.

We regret that two unfortunate typographical errors crept into a formula appearing on page 614, E.W. & W.E., July. This was in Mr. S. Butterworth's article on "High Frequency Copper Losses in Inductance Coils."

The formula for the resistance of single-layer, short solenoids was given as

$$R' = R\left\{1 + F + \left(3{\cdot}29 + \frac{b}{2}\right) - \frac{d^2}{D^2}\,G\right\}$$

instead of

$$R' = R\left\{1 + F + \left(3{\cdot}29 + \frac{b}{a}\right)\frac{d^2}{D^2}\,G\right\}$$

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Rectifiers for High-Tension Supply.

Part I: Mechanical Rectifiers. [R555·5

By R. Mines, B.Sc.

The first part of a short series treating this interesting subject in detail.

BROADLY speaking, a rectifier (or sometimes "detector") is no more than an "assymmetric conductor," that is, a conductor whose electrical behaviour is different for positive and negative applied voltages. It will be realised, however, that when such apparatus is to be used for obtaining high-tension power from an alternating source, the ratio between the powers passed by it in the two directions must be taken into account, as it is an important factor in the efficiency of the combination. It is desirable, in fact, to use only those types of apparatus that offer a complete block to the passage of current in one direction (called "perfect rectifiers"); hence the definition given in our previous article (E.W. & W.E., p. 580, July, 1924)—"an apparatus that will allow current to flow through it in one direction only when an alternating P.D. is applied to it."

The knowledge that the direction of flow of current in a circuit may be controlled by a mechanical device, called a "switch," leads to the suggestion that such a switch may be used for rectifying an alternating supply. It must be realised at the outset,

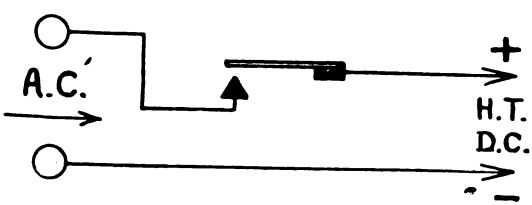

Fig. 1. *Half-wave rectification—single-pole switch synchronously operated.*

however, that to make full use of the supply the switch must perform a complete cycle of operations for each cycle of the alternating supply, whatever the frequency of this may be. To comply with this condition, for supplies at the usual power frequencies, two main types of rectifier have been evolved, viz., the vibratory or "reed" type, and the rotary or "commutator" type.

One of the main advantages of the mechanical rectifier is the direct control that may be exerted on the cycle of operations—the instants of making and breaking the connection in either direction, *i.e.*, the "duration" and the "phase"

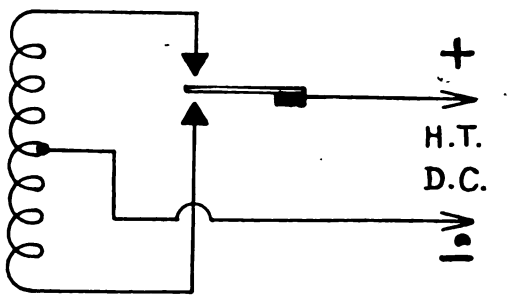

Fig. 2. *Full-wave rectification, with two-way switch and mid-point tap.*

of the contact may be chosen within wide limits to suit the work in hand, and if desired may be made variable during the running of the apparatus.

Vibratory Type.

As suggested in the article referred to above, let us consider the high-tension circuit as having a constant P.D. maintained at its input terminals, so that supplying power to the circuit must consist in pumping current against this steady P.D. The problem then becomes analogous to the low-tension one of charging accumulators from an alternating supply.

(*a*) The simplest method that presents itself is to use a "single-pole one-way" switch, as shown in Fig. 1. The operating mechanism of the switch (to be described later) must be arranged to close the circuit for as long as the supply P.D. is sufficiently high and in the correct direction to drive current into the high-tension circuit, and to keep the circuit open for the remainder of the cycle of the alternating supply. The

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P.D. relations, the current pulses flowing, and the "back E.M.F." which the switch must withstand, are similar to those in the general case, described on p. 581 of E.W. & W.E., July, 1924, and illustrated in Figs. 1 (*b*) and (*c*) thereof.

(*b*) "Full-wave" rectification may be obtained from two transformers or one with a mid-point tapping on its secondary by using a "single-pole two-way" switch as shown in Fig. 2. This corresponds in a similar manner to the second method described (see Figs. 2 (*b*) and (*c*) of July article).

(*c*) The same result may be obtained without the necessity of a second transformer or a mid-point tapping by using a "double-pole" switching device instead of a "single-pole" one. The arrangement is shown in Fig. 3; the two switch-arms shown have to work in step with one another, which may be accomplished by mechanical coupling or similar means, so that no addition to the operating mechanism is involved. A modification is shown in Fig. 4 which requires only one vibrating armature; but this must carry two contact plates as

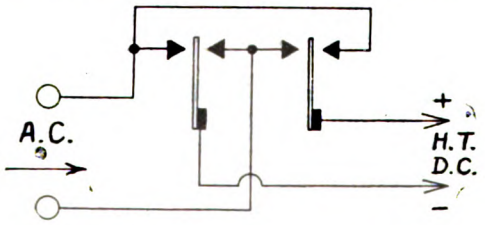

Fig. 3. *Full-wave rectification without mid-point tap, using double-pole switch.*

shown, insulated to withstand the full D.C. P.D., between them.

(*d*) In Fig. 5 is shown the vibratory rectifier applied to the Coolidge and Hull method of rectification; the rectifier is of the "single-pole two-way" type, as used in method (*b*) above.

Operating Mechanism.

Since the moving contacts of the switch have to operate in synchronism with the alternating supply, a solenoid excited with A.C. from this supply and acting on a magnetic armature which carries the moving contacts, affords a solution that is at once simple and effective. It should be noted in passing that the magnetic armature must be "polarised," else it will give a double frequency of motion. More simply, a soft iron armature changes its polarity with that of the solenoid, by induction, and hence is attracted for each maximum value of the A.C. (in either direction) and released for each time the A.C. passes through zero. On the other hand, "polarising" the armature (*i.e.*, giving it a fixed magnetic polarity) makes it sensitive to the direction of the magnetic flux; it is attracted at the maximum values of the A.C. in one direction, but is repelled at those in the opposite direction.

It is necessary now to consider what means can be adopted for "timing" the making and the breaking of the contact. In general, with this type of rectifier, the "contact time" or duration of contact may be controlled directly by either or both of two factors: (1) The position of the fixed contacts relative to the vibrating contact; (2) the amplitude of vibration of the moving contact. In practice it will be found most convenient first to obtain an approximate value of (2) by choosing a suitable size of driving solenoid; then final setting to the working conditions is obtained on (1), which is usually a screw adjustment. Next, the correct phase relation must be established between the switch movement and the supply alternations, and to do this, use may be made of the inductive property of the driving solenoid—that the current flowing through it lags behind the supply P.D. by some angle less than 90°. By connecting external resistance in series with the solenoid, this angle may be reduced to a few degrees; and if a condenser is used it may be taken past zero and the current caused to lead the supply P.D. By reversing the connections to the solenoid, the considerable range of adjustment thus made available may be doubled. Perhaps it is hardly necessary to point out that controlling the phase of the solenoid current affects the phase of the motion of the vibrating contact through the intermediary of the flux produced by the solenoid.

In such a tuned reed rectifier, Simmonds[1] finds that sufficient control is obtained on a 50-cycle supply by using only a series resistance (maximum value, 300 ohms). He also states that he relies on adjustment

[1] Simmonds, "The Construction of a Tuned Reed Rectifier," E.W. & W.E., January, 1924, p. 221.

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of this resistance to obtain sparkless operation under varying working conditions, without alteration of the screw adjustment of the fixed contact.

The Moving Contact.

There are two kinds of moving armature in use; they may be denoted by the

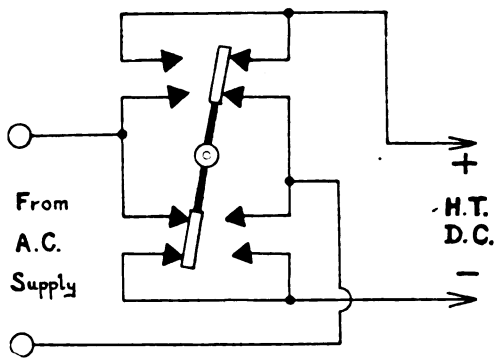

Fig. 4. *Same as Fig. 3, but with an alternative form of switch.*

terms "tuned," and "free" (or so-called "aperiodic"). As may be gathered from the name, the tuned armature consists of a mechanical oscillatory system, having a natural frequency which is made equal to that of the alternating supply. Thus, in operation the system is vibrating in resonance, and as is well known the maximum amplitude of vibration is obtainable under this condition; herein lies one of the advantages of using a tuned armature. Simmonds (*loc. cit.*) uses as armature a flat strip or "reed" of spring steel, the dimensions being chosen so that it resonates with the supply frequency of 50 cycles per second.

Generally speaking, however, the difficulties of making a tuned armature operate satisfactorily increase with rise in frequency, for even though the condition of resonance is still used the amplitude obtainable in the mechanical vibration falls off rapidly. This effect may be noted in the case of the "Microphone Hummer" used to generate alternating current at 800 cycles per second for telephony testing work. In this apparatus the steel reed and its mounting block are cut from the solid; the amplitude of vibration is very small (measured in thousandths of an inch) so that operation is rendered possible only by use of a sensitive microphone worked by the reed in place of a make-and-break contact.

The free type is in general an armature whose natural frequency of vibration is very low, this being secured by weakening the elastic controlling force rather than by increasing the moment of inertia (dependent on the mass). Thus, in normal operation the armature executes "forced vibrations" at a frequency considerably above its natural frequency. An example of this type is the Army "D Mark III." Telegraph Vibrator, which is essentially a high-pitched buzzer normally operating at a frequency between 150 and 500 cycles per second. Dyer[2] describes the adaptation of this instrument as a full-wave rectifier, working at the frequency of a public supply. In view of its performance as a buzzer, working from dry cells, there should be no difficulty in securing satisfactory rectification from a power supply at higher frequencies, *e.g.*, 500 cycles per second as is obtained from the small wind-driven alternators.

"Voltage" Limitations.

The rectifiers developed by Simmonds and Dyer were both designed for low-tension operation, *i.e.*, the charging of accumulators. The latter states, however, that his apparatus operates satisfactorily direct on the 200-volt supply. It is recognised as desirable that the time of breaking circuit should be adjusted as closely as possible to the instant when current ceases to flow, if only to secure

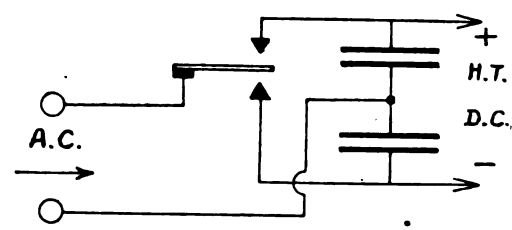

Fig. 5. *Full-wave rectification—"Pulses" delivered to the two halves of the D.C. circuit in series.*

maximum life of the contacts. If in addition to this, the time of making contact can be sufficiently closely adjusted to the instant when the P.D. between the contacts reaches zero, then the following condition is obtained: That the P.D. between the separated contacts (whose maximum value is the "back E.M.F." on the rectifier) is approximately proportional to the distance

[2] Dyer, A Full Wave Rectifier, E.W. & W.E., September, 1924, p. 728.

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between the contact surfaces. Thus, having eliminated all tendency to sparking, the next limit that imposes itself is the breakdown strength of the air-gap between the separated contacts. Needless to say a fairly

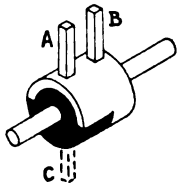

Fig. 6.

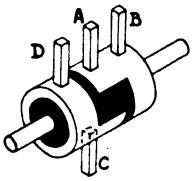

Fig. 7.

Fig. 6. *"Single-pole" commutator—one-way (brushes A and B only), or two-way (all three brushes in use).*
Fig. 7. *"Reversing" commutator.*

large factor of safety must be allowed in this respect, but if a reasonable amplitude of vibration is obtainable the P.D. rectified may be raised to cover most of the requirements of the radio worker.

Rotary Type.

It must be confessed at the outset that the operating mechanism required for a vibratory type of rectifier is inherently simpler and cheaper for the radio experimenter to install than a motor with shaft and bearings, such as is necessary for driving rotary apparatus (sometimes, however, there is available the shaft of the alternator generating the supply to be rectified, to which the rotary rectifier may be coupled). But in any case we shall see that rectifiers of the rotary type possess many advantages over those of the vibratory type, in respect of frequency, P.D., and current for which they may be designed.

The most elementary form is a drum, part of whose surface is conducting and part insulating, with a brush A bearing upon it (Fig. 6), the conducting part being connected to the external circuit through the shaft and bearing or preferably through a "slip-ring" to a second brush *B*. In practice it is convenient to make the slip-ring and conducting part in one piece; the arrangement constitutes a "single-pole one-way" switch.

To convert this into a "two-way" switch (to obtain "full-wave" rectification) it is necessary only to add a third brush "*C*" diametrically opposite the first, so that on rotating the drum the conducting part establishes connection from brush *B* alternately to the brushes *A* and *C*.

By mounting two conducting parts with their slip-rings on the same drum, and using six brushes, a standard "double-pole two-

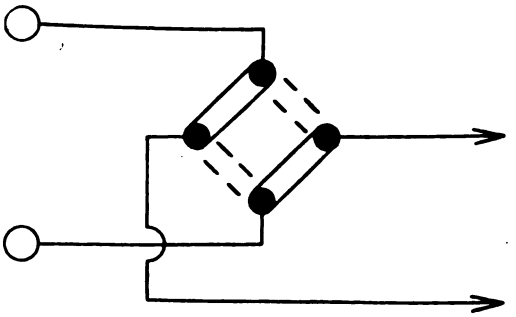

Fig. 9. *Four-point reversing switch.*

way" switch is produced (corresponding to Fig. 3). Actually, however, method (*c*) above requires not a complete "six-point" switch such as this, but a "reversing switch" ("four-point," or having four terminals); the paralleled connections indicate that certain parts may be coalesced, as shown in Fig. 7 (here only four brushes are needed). The connections may be represented as in Fig. 8, which it will be seen corresponds to Fig. 4.

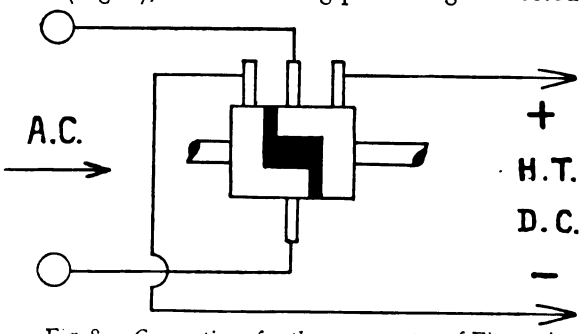

Fig. 8. *Connections for the commutator of* Fig. 7, *in use as rectifier.*

Alternative Arrangement.

For purposes of distinction the arrangement evolved above may be denoted as the "slip-ring" type of rectifier. For there is an alternative way of producing the same result as Fig. 7, which possesses certain distinguishing characteristics as described in a later section.

This type may be described as the "interrupter" type, since in method of working it resembles the rotary interrupter switches that are used for induction coils, for "contact" methods of wave-form delineation, and for capacity measurement. It is

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a direct application of the "four-point reversing switch" (Fig. 9), and is shown complete with connections in Fig. 10.

One of the advantages of this type is its slower speed of rotation for the same supply frequency; for it performs two complete cycles of operation for each revolution, instead of one.

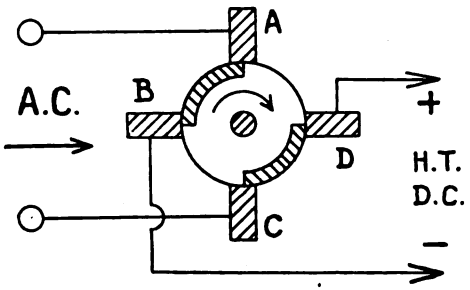

Fig. 10. *"Interrupter" type of commutator.*

Timing.

With the rotary rectifier it is possible to exert independent positive control over the two factors, the "phase" and the "duration" of the contact. The phase of contact depends on the relative angular positions of the brushes *A* and *C* (Fig. 7), and the stator of the motor (or alternator) by which the commutator is driven. The brushes can be mounted on some form of rocker arm, just as is done in D.C. electric motors, so that rotation of this arm gives the required chase variation. Alternatively, the rotation may be made at the driving machine, as is done by Butement.[3]

The duration of contact is dependent on the design of the commutator and the brushes. Fig. 11 is a cross-section of the commutator of Fig. 7 taken in the plane of the brushes A and C; (*a*) shows the position of making contact, and (*b*) that of breaking. By superposing the figures it is seen that the angle through which the commutator rotates while contact is established is $\theta+b$, where θ is the angle subtended at the centre by each conducting part, and b that subtended by each brush. Now this rectifier makes a complete revolution for each cycle of the alternating supply; therefore the duration of contact is $(\theta+b)/360$ of a period (if the angles are measured in degrees).

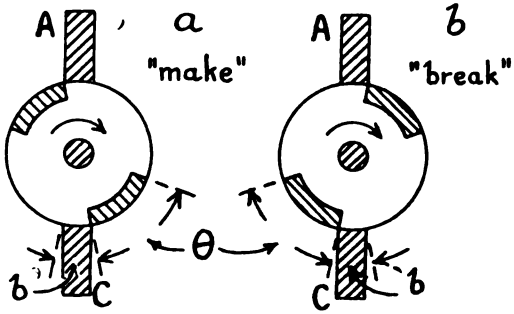

Fig. 11. *Illustrating the timing relations of the slip-ring type of commutator.*

To simplify the handling of the formulæ, this interval of time is called "$\theta+b$ electrical degrees."

This quantity becomes variable only if θ or b can be varied. By using two sets of brushes, connected together electrically, the arc covered by the brushes may be varied between certain limits. If the two sets of brushes are mounted in different planes so that they may be set opposite each other (showing as in Fig. 11), the lower limit is the width of each individual brush (which we shall continue to call "b"). Then the minimum contact time is $\theta+b$. Alternatively the two sets may be moved apart (this must be done symmetrically so that the phase adjustment shall not be disturbed), as far as the point where the gap between the brushes of the two sets equals the width θ of the conducting part on the commutator, as shown in Fig. 12. This is the limiting position, because with a larger gap contact would be broken and discontinuity established. The arc commanded

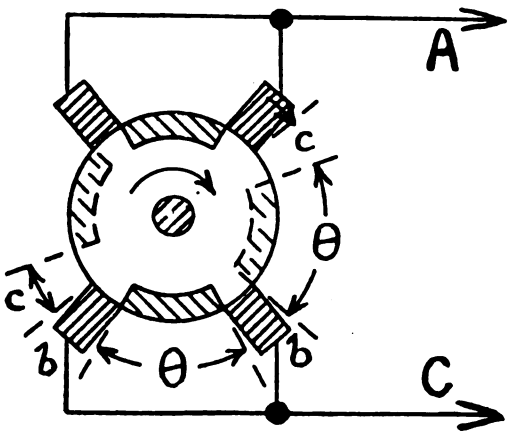

Fig. 12. *Illustrating the limiting conditions in the design.*

[3] A. Butement. A Simple Rotary Rectifier. E.W. & W.E., August, 1924, page 658.

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by the brushes is now $2b+\theta$, and the maximum contact time has become $2\theta+2b$, *i.e.*, twice the minimum value.

A further limit must at this point be investigated. Imagine the conducting parts to be in the position shown "dotted" in Fig. 12. If the width θ were made so large

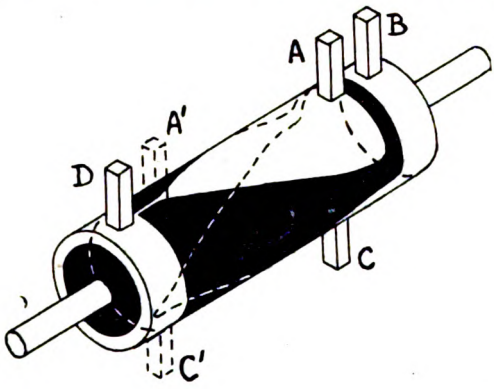

Fig. 13. *Commutator with varying segment angle —brushes A and C have axial traverse.*

as to bridge the gap between the brushes connected to opposite poles, a short-circuit would occur. From Fig. 12, the width of this gap is found to be $180°-(2b+\theta)$. Further, in practice it is necessary to allow a definite clearance "c" to prevent flash-over with medium and high P.D.s. The maximum permissible value that θ may be given is therefore fixed by the following relation :—

$$\theta+c=180°-2b-\theta,$$

which gives,

$$\theta_{(max.)}=90°-b-c/2.$$

Substituting the maximum contact time obtainable with this apparatus is

$$2(\theta+b)=180°-c.$$

The method involving variation of θ for control of the contact time carries with it the disadvantage of requiring a special type of commutator, although the two symmetrically-adjustable sets of brushes are no longer necessary. The conducting parts are tapered, so that they have their maximum width ("$\theta_{(max.)}$" above) at one end, and their minimum width (which may be made practically zero) at the other end of the commutator. This design is depicted in Fig. 13. The brushes A and C are mounted on a frame so that they can be traversed axially along the commutator from one end of the triangular-shaped conducting parts to the other.

Here the minimum permissible gap between adjacent parts of opposite polarity is $b+c$; so that $\theta_{(max.)}=180°-(b+c)$. By substitution, the maximum contact time is $180°-c$, the same value as with the preceding arrangement. The minimum value of θ may be called zero, so that the minimum contact time becomes b. This may be considerably less than half the maximum value, showing an advantage over the preceding method.

Timing of the Interrupter Type.

The time relations of the interrupter type of rectifier may be analysed on similar lines. As before, control of the duration of contact may be obtained by two methods —by using two sets of brushes with equal and opposite rotation, or by using tapered conducting parts on the commutator and brushes with an axial traverse.

Figs. 14 (a) and (b) show the positions at "make" and "break" respectively; the brushes A and C are "doubled" and command an arc ϕ; those at B and D remain single and have a width a. By superposing the figures the contact time may be evaluated; thus the angle of revolution during which contact is established is $(a+\phi)+\theta-90°$. Since there are two cycles per revolution, the contact time in electrical degrees is twice this, *i.e.*, $a+\phi+2\theta-180°$. Notice here that by sufficient reduction of ϕ or θ or both, the contact time may be made zero or negative (mathematically speaking), whereas with the slip-ring type the minimum contact time is b electrical degrees. (This property is of most use in selecting extreme peaks of a P.D. wave, such as for running an X-Ray tube from an induction coil.)

As with the slip-ring type, short-circuit occurs when a conducting part bridges the smallest gap between brushes of opposite polarity; the width of this gap is $180°-\phi$, and allowing the clearance, c, we have the relation

$$\theta+c=180°-\phi$$

giving

$$\theta_{(max.)}=180°-c-\phi,$$

and

$$\phi_{(max.)}=180°-c-\theta.$$

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By substitution the maximum contact time obtainable is $180° + a - 2c - \phi$ in terms of ϕ as variable, or $a - c + \theta$ in terms of θ as variable.

In working out concrete examples from these formulæ, such as by choosing the minimum and maximum contact times and working backwards, it must be remembered that θ cannot become less than zero, ϕ cannot become less than a, and c must be assigned a value appropriate to the P.D. to be used. In general it will be found that the maximum contact time obtainable with this apparatus is much smaller than with the "slip-ring" type; but it is sufficient for most high-tension work.

"Multipolar" Commutators.

The "slip-ring" commutator may be made in the "four-pole" form, giving two cycles per revolution, like the "interrupter" type; it is shown thus in Fig. 15. The

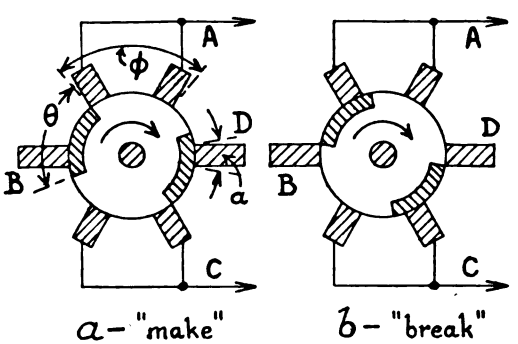

Fig. 14. *Illustrating the timing relations of the Interrupter type of commutator.*

commutator has four conducting parts instead of two; but no additional brushes are required. Note, however, that the brush C must retain its 180 electrical degrees of phase displacement with respect to brush A, and this becomes a space angle of *half* the amount, *i.e.*, 90°.

Similarly either type of commutator may be designed for any number of cycles per revolution, giving control over the speed of revolution independently of the frequency of the supply. In rotating machinery the limit experienced at high speeds is that imposed by centrifugal force, and this is proportional to N^2D, where N measures the speed of rotation and D the diameter of the commutator. Having fixed the P.D. at which the commutator is to operate, the contact time required, and the size of brush to carry the current, the design of the commutator may be completed at least as far as concerns fixing the peripheral width that shall be occupied by 360 electrical degrees. The diameter D then will be proportional to the number of cycles per revolution. Further, for a given frequency, the speed N is inversely proportional to this same number; as a result the product ND becomes a constant. Substitute this constant in the factor for the centrifugal force, and it is found that this force becomes proportional to N, the speed.

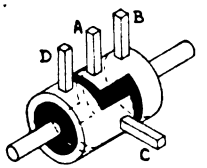

Fig. 15. *A "four-pole" slip-ring commutator, corresponding to the interrupter commutator of Fig. 10.*

Thus, with high P.D.s, which necessitate liberal clearances in the commutator design, or high frequencies, or both, the centrifugal force may be brought within the limits of safety by increasing the diameter (and number of cycles per revolution) of the commutator, and thus decreasing its speed. The only limit is the cost of construction, and in some cases the space occupied. Note that the driving machine must operate with the same number of cycles per revolution as the commutator which it is to drive.

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The Perfect Set. [R342·4

Part XI: More about the Reflex; and Conclusion.

This month we conclude our series, since the only possible extension—a consideration of the super-heterodyne principles—at the moment is impossible owing to the fact that there is still a large amount of experimental work to be done.

IN Parts IX. and X. of this series we have described some general properties of Reflex or Dual Amplification and have applied ourselves to the detailed consideration of a typical circuit. It is now proposed to consider some of the most important variations from this type. By way of reminder, we reproduce herewith our illustration of the typical circuit.

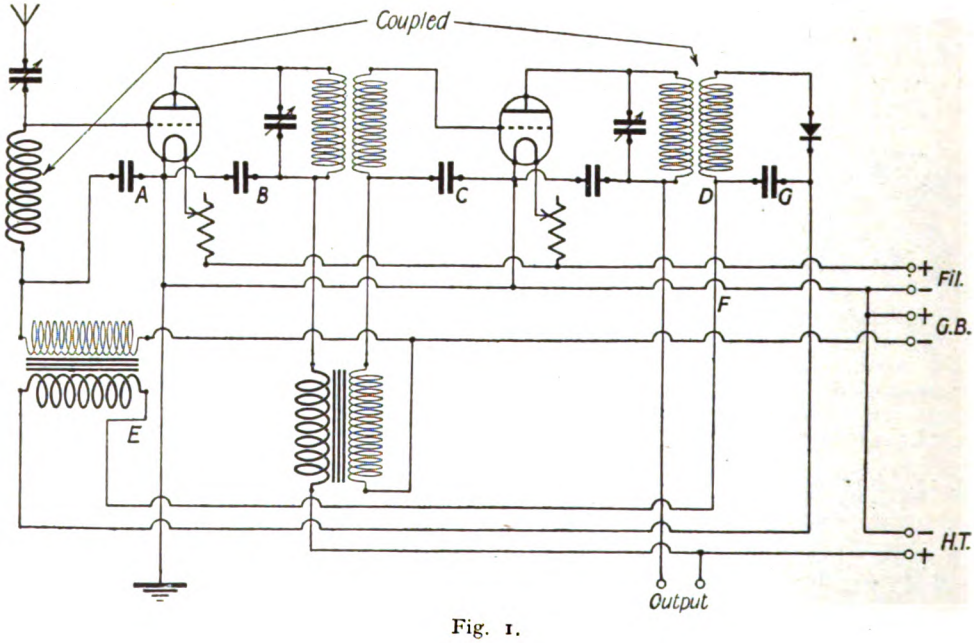

Fig. 1.

Series and Parallel Couplings.

Perhaps the most important variation is that in which the H.F. and L.F. couplings between any given points, instead of being in series as in Fig. 1, are in parallel. Thus, in Fig. 2,*a* shows the typical anode circuit, with the primaries of an H.F. and an L.F. transformer in series, the H.F. currents being led round the latter by the by-pass condenser *C*. In Fig. 2*b*, these two instruments are in parallel. To separate the two components of the combined H.L. and L.F. current, we provide the stop condenser C_1 and the H.F. choke L_1.

Theoretically, these two circuits should behave identically as regards their real function, leaving one free to choose between them on the grounds of secondary effects. In practice, owing to the unavoidable self-capacity of L_1 and other minor difficulties, the parallel connection is not quite so good as the other. One point is that if one wishes to cover a wide range of wave-lengths one should change both L_1 and C_1, while in circuit 2*a* there is only *C* to change.

It is sometimes claimed that *b* is the better owing to the absence of the by-pass condenser *C* across the L.F. transformer. But careful

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examination of *b* shows that C_1 is across the transformer for L.F. currents, so nothing is gained. A real difference is that in *b* the point *E*, at the lower end of the H.F. coupling, is directly connected to the filament, and this gives us the clue to the one point in the set at which this connection has real advantages. Looking at Fig. 1 we see that the aerial circuit has two series condensers. The range of wave-length obtainable by varying the tuning condenser is rather small, because, however large we make it, the total capacity in series cannot be greater than that of the rather small by-pass condenser. We can get a larger range of wave-length by using a condenser across the A.T.I., but at the cost of efficiency.

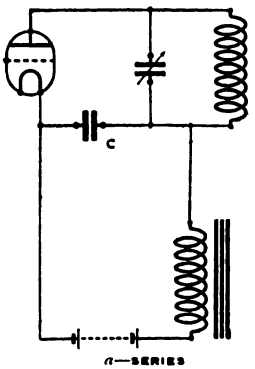

Fig. 3 shows how the difficulty is avoided by using the parallel connection. For broadcast wave-length C_1 should be of the same value as the original by-pass condenser in Fig. 1, say .000 1μF, while L_1 may be a coil of anything from, say, 1 500μH upwards—a 200- or 600-turn coil of the usual size will do—but it must be of a make having really low self-capacity. One point to be noticed is that the introduction of C_1 may lead to a tendency for the first valve to rectify, and this must be avoided carefully by proper attention to grid bias and H.T. voltage. For the other coupling circuits the author's personal preference is for the series connection, as in Fig. 2*a*.

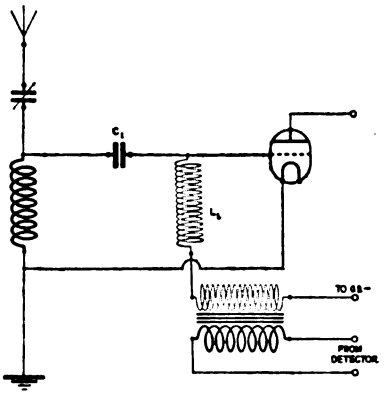

Fig. 3.

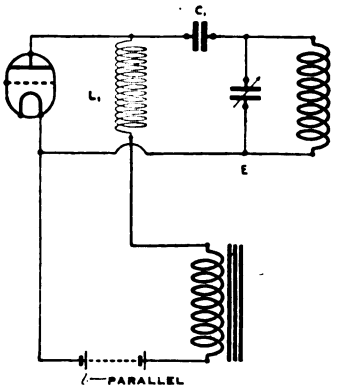

Fig. 2.

Inverse Dual Amplification.

The next great field for variation lies in the choice between "direct" and "inverse" arrangements, credit for the invention of the latter being due to Grimes of America. The essential difference is shown in Fig. 4, which gives the simplest possible graphic explanation, the line simply representing the course of signals.

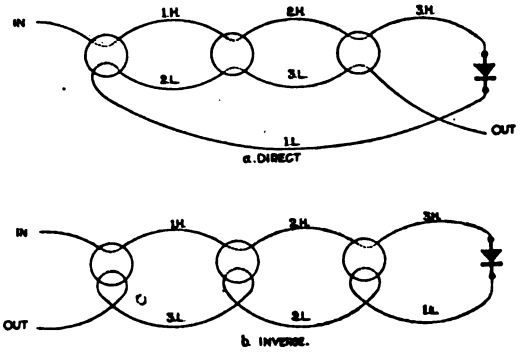

Fig. 4.

Fig. 5 shows the typical wiring diagram of such a circuit, and should be compared with Fig. 1.

This arrangement has one definite advantage, which we will deal with shortly. There is also claimed for it an advantage which is quite fallacious. This is that, since the last H.F. valve is the first L.F., and *vice versa*, the total load on the valves is equalised.

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As we have stated already, this is quite a mistake. A few minutes' work based on the known amplification of the valves at high and low frequencies shows that the L.F. input voltages are so large compared with the H.F. that the "equalisation" is quite illusory, the change in the total load on the heaviest-loaded valve being of the order of 1 per cent. on changing from one type of circuit to the other.

The real advantage is this: suppose that some audio-frequency interference, such as hum from electric mains, etc., is induced into the aerial. With the "direct" connections, Fig. 4*a*, it will be amplified by several stages before reaching the output: in the case of the Grimes inverse, it will be amplified by one stage only.

But there is a very serious disadvantage. It is absolutely essential in the inverse circuit that there shall be a complete separation of the two current components in the intervalve couplings; in other words the H.F. transformer must on no account pass *any* L.F. output from its primary to its secondary, nor must the L.F. transformer pass any H.F. For consider the first valve in Fig. 5. It is amplifying L.F. from transformer *E*, and the L.F. output is supposed to go to the output terminals. But if any L.F. gets through the H.F. transformer to the grid of the second valve, then this second valve is having part of its own output returned (*via E* and the first valve) to its own grid—in fact there is L.F. reaction. Similarly there will be H.F. reaction if any H.F. gets through an L.F. transformer.

Now in practice one can, with care, avoid any noticeable effects of this kind on short-wave sets not using many stages. But outside these limits we ourselves have found so much trouble that we have given up the inverse.

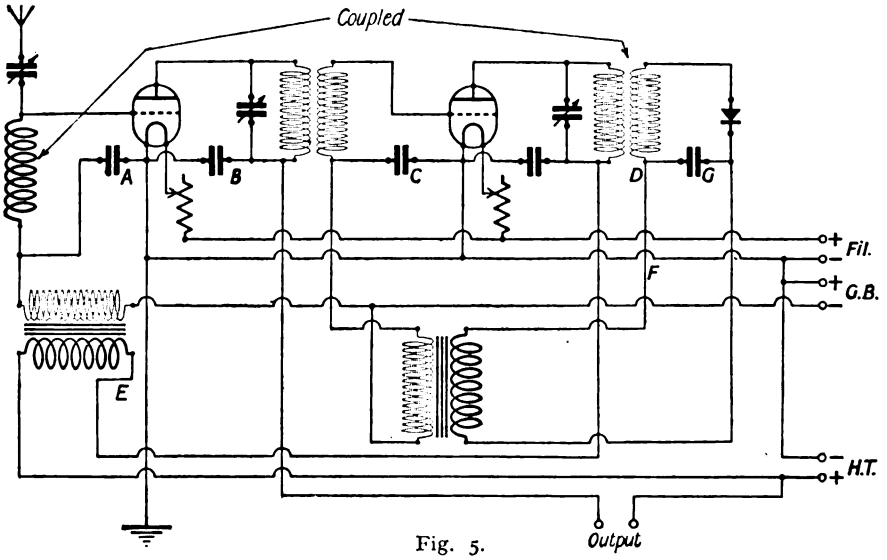

Fig. 5.

In fairness, we must note that there is a possibility of a similar trouble in the "direct" circuit of Fig. 1. Here, it does not matter at all as regards the general intervalve coupling—in fact for long-wave telegraphy one can get quite good results with a single transformer for each stage. But it must not be forgotten that there is an H.F. component in the rectified output from the crystal, and that if any of this gets through to the grid there is H.F. reaction over the whole set. In this case, however, the trouble is localised in one spot, and can be dealt with easily.

As mentioned in Part X., a large value (say .001μF) for *G* is a solution for short waves, and in practice we have had little difficulty up to 15 000 metres with values of *G* up to .005μF. In rare cases, as perhaps in that where the "H.F." is really the "intermediate amplifier" of a multi-stage supersonic set, it may be advisable to substitute a filter for the simple condenser *G*. Such a filter is mentioned in a special article on filters in this issue (see p. 673).

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Other Intervalve Couplings.

Hitherto we have confined our remarks to circuits using transformer coupling; and this is for the reason that, as will be remembered from the earlier instalments on H.F. and L.F. amplification separately, our personal view is that transformer coupling is the best for such work as reflex sets are best fitted to do. It is not, however, by any means an essential that this coupling should be used. Fig. 6 shows a coupling using choke coupling for the L.F. and either choke or "tuned anode" for the H.F. according as the dotted condenser is omitted or included. The separate choke for H.F. is necessary, since it is practically impossible to build the L.F. choke of low enough self-capacity to stop H.F. currents. The main difficulty is with regard to the coupling condenser. This must be large enough to handle L.F. currents (say .05μF), and therefore particular care must be taken to use enough grid bias, as otherwise the second valve may be out of action as an amplifier for periods of 1/100 sec. or so—a long time when one considers H.F. currents.

If resistance coupling is desired it may be used in the same way, substituting a single resistance of low capacity for both chokes. Hitherto, however, we have not found the perfect resistance for this purpose: wire-wound resistances usually have too great a self-capacity. It is possible that an H.F. choke or tuned anode, as in Fig. 6, followed by a wire-wound resistance instead of the L.F. choke there shown, might meet the case. But there is still the difficulty with regard to the coupling condenser.

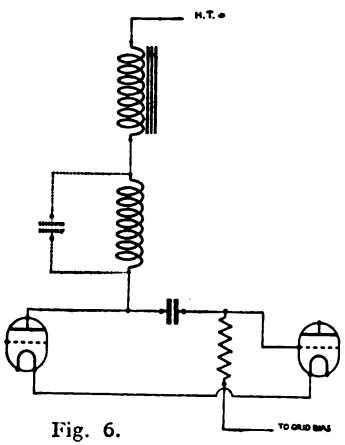

Fig. 6.

Extra-simple Reflex Sets.

In many cases sets can be designed using the dual amplification idea, but without the necessity of any double intervalve coupling. This occurs, for example, in the single valve reflex, which, followed by one stage of power amplification, makes a most admirable loud-speaker receiver for "suburban" broadcast work, giving ample strength up to 30 miles or so from a typical B.B.C. station. Such a

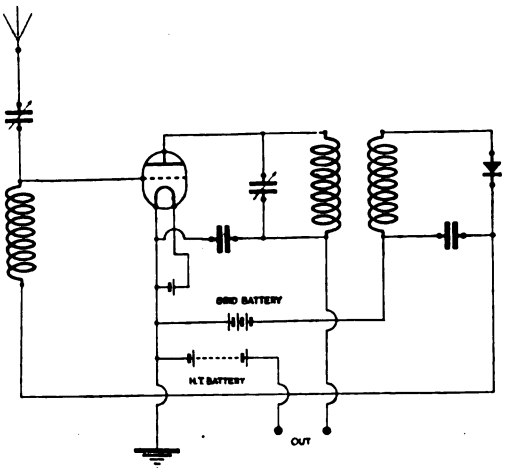

Fig. 7.

set can be made to give very fine musical quality. At some sacrifice of signal strength a single-valve set may be built without any L.F. transformer at all, the arrangement being as in Fig. 7—the main idea due to Voigt. Obviously the output may go *via* a transformer to a stage of L.F. amplification.

This, however, loses the effect of the step up in the crystal-to-valve transformer, and as this may be of high ratio a considerable gain can be got. Probably the best local loud-speaker set is that shown in Fig. 8. This, with the addition of an on-off switch, a combined H.T. milliammeter and filament voltmeter, and a few definite instructions, can be put in the hands of a maiden aunt with complete confidence. The values of components necessary can be gathered from earlier parts of this series.

Conclusion.

This series has now covered the essentials of crystal and valve rectification, and amplification either H.F., L.F., or both; and we believe that this is an appropriate point at which to conclude it. Not that we are congratulating ourselves on having completely settled all wireless problems, but that our particular object—to deal with some of the neglected essentials of well-known types of set—is more or less accomplished.

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Originally it had been our intention to extend the series to cover the supersonic set; but after mature consideration we have decided not to do so. These articles embody the results of several years' experience on each point dealt with, and, although we have had some experience on supersonics, we do not feel justified yet in writing articles of this type about them. Perhaps we may describe in another article some ideas that we have gained from our work on them, but that is very different from "laying down the law," as we have presumed to do in this series.

One last word. In the course of our discussions of various types of set we have shown, now and again, circuit diagrams. Various readers have written saying that they want to build a set accordingly, and rebuking us because the diagrams contained insufficient particulars. We should like to state quite plainly that these diagrams are only the *groundwork* of set design. These are all the matters of switchgear, tuning devices, battery voltages, and so forth, to be decided. It is not the idea of E.W. & W.E. to give particulars by which all readers can build identical sets. What we try to do is to give the *basis* on which the readers can design his own set.

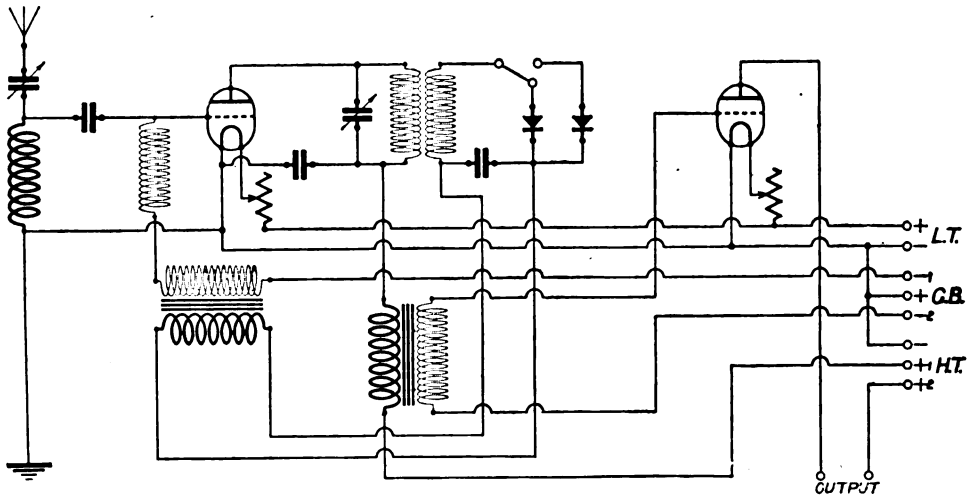

Fig. 8.

This series has been a labour of love: we hope that it has been of use to some readers.

P. K. T.

A Standard Report-Card

By M. T. Coode. **[R623·23**

IT seems that in America there exists a form of report-card which has become standardised through general, unspoken consent; but in England one has to go to the trouble and expense of writing one's own card or of having it printed privately. For these reasons there are several advantages in having a standard report-card which could be printed conveniently. Were this the case the transmitting amateur would find his reports many times more valuable and far easier to classify, while the receiving amateur would be saved time, trouble and expense. If a publisher were to print a card of this kind, it would cost little more than a plain postcard, and should go through the post for a halfpenny (a big consideration for an amateur who logs, and would like to report, more than a hundred amateurs on some days).

That reproduced herewith seems the most suitable form of report-card. Of course,

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a letter is nearly always preferable to a card for exchange of opinions after two-way working, but the card is designed for the amateur who is not in communication with another amateur, but is picking up whom he can.

The author would like to maintain the advantage of using a card index at a receiving station in preference to a log-book. The former can be rapidly compiled from the message forms used while receiving, or might well consist of duplicate report-cards. Since the cards could be arranged in (alphabetical) order of the call signs received—which appear at the top left-hand corner of the card—reference could be made easily. In addition a small log-book of dates and call signs heard, which must necessarily be entered in chronological order, could be made without trouble, and would be quite useful.

In the report-card the author has indicated the "R" method of measuring signal strength chiefly for want of a better one. All simple and inexpensive methods put forward to date, such as shunted phones, depend more on the listener's ear than does the "R" method. Besides this any measuring instrument having a control needs another hand as well as those for tuning and writing! Nor would anyone like the experience of finding the station whose signal strength he was trying to measure to several places of decimals close down when he was half-way through the delicate operations which accurate and rather unnecessary measurements must entail. In any case, the "R" method has become standard and has been proved to be consistently sure in the Army and elsewhere.

The method of describing the receiving set is one which has now become standard, and which has the advantage of being short. A dash over the V seems the easiest way of denoting reaction, but is not in any way original. The space left for the type of receiver is obviously necessary: some description of the receiver must be given, as no report can be completely accurate when the signal strength is given without any indication of the efficiency of the set, although the "R" method eliminates errors due to this fairly well. It will be much better to give these details until some method of measuring the strength of signals before reaching the aerial is discovered.

Fading, atmospherics and jamming are obviously of importance to the transmitting amateur, while it is a good thing to give the distance between the two stations if it is known, as he may not be able to find out so easily for himself.

Some long distance amateurs use a code word besides their call sign and this is usually sufficient for the identification of the message. If a code word is not used, some outstanding part of the message should be given, for mistaken call signs are more frequent than would seem possible.

The form given below has been typed quite easily on a fair-sized postcard, and when printed there would be sufficient room for remarks which cannot be classified under a separate heading. To make this report-card really useful it should be in agreement with the ideas of every amateur, and to get as near this as possible criticism of the form given below is essential and will therefore be welcomed, so that a final card can be drawn up.

(Receiver's Call Sign)

Address .....

.....

Date .....

7 ABC was heard calling *9* on *10.12.25* at *13.20* hours G.M.T.

Signal Strength R *5* λ *440* *no* fading, QRM *jamming, no* X's.

QRB *98* miles. Receiver *O-V-O, Reinartz.* Aerial system 100′ × 40′ *cpse.* Code word and/or identification *ZADO, "Am receiving you well."*

Remarks *"Modulation good."*

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6TM. An Amateur Station.

By W. A. S. Butement. [R612

LIKE many others this station had to be constructed under considerable financial difficulties: the total cost of the entire station, including the aerial and the receiver, was less than £15.

The station is situated on the edge of a small ridge, running north and south, in West Hampstead, London. (The exact QRA for purposes of reference is 127, West End Lane.) The location is far from ideal, and it is surprising that such long ranges have been obtained, using so little power and with an aerial system of the type installed.

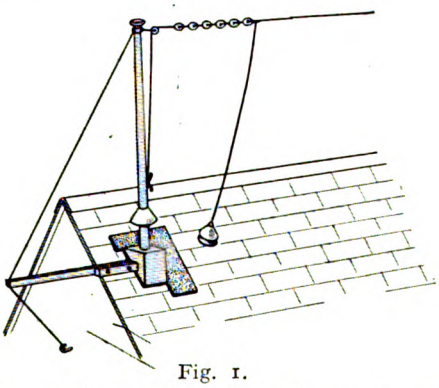

Fig. 1.

The problem of the aerial was the first real difficulty when transmission was seriously contemplated in August, 1924. The house is about 50 feet high with a very steep roof of slate. It was eventually decided to cut two holes in the roof, one at each end and about 45 feet apart, and to erect masts on the roof from these holes. With much difficulty the holes were cut and fitted with lids, and the erection of the masts was the next problem.

Two poles about 15 feet in length were obtained, and these had to be hauled up the side of the house, with the head and shoulders only of the "hauler" protruding through the hole. The final method of fixture is shown in Fig 1.

These two masts, being accessible from inside, form a very convenient support for almost any type of aerial, and various systems have been compared. Apart from its accessability, the aerial is held very rigidly between the masts, and can be pulled quite tight, so that it cannot swing in the wind. This is not the case with an aerial attached to a tree, where, to obtain an absolutely steady note in windy weather, it is necessary to employ a master oscillator set.

Many different aerials were tried between these masts, but the system which gave the best all-round results, was a single strand of 16-gauge enamelled copper wire, forming an inverted L. This was 42 feet long, 10 feet above the roof and well insulated at both ends (see Fig. 2).

The counterpoise consisted of four similar gauge wires, four feet apart and 45 feet long. This is situated *inside* the roof and about three feet from the top. Thus almost the whole roof is between the aerial and counterpoise.

Strangely enough, the results obtained with the counterpoise just outside the roof were in no case as good as those obtained with the system described above, even though 50 per cent. more aerial current was obtained. With either system, however, the results in wet and dry weather were very different: in wet weather no really reliable results could be obtained at all.

Every "earthed" body within reach is connected to the transmitting inductance, each one being brought into resonance with the rest by tapping it on to an appropriate turn of the inductance. To find these positions accurately for a number of "earth" leads took quite a long time, the positions of

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the various leads being continually changed until the aerial current as shown by the meter was at a maximum.

This assumes, of course, that the position of the nodal point does not shift during these changes; this can be verified, either with a neon lamp, or, more simply, on moderate

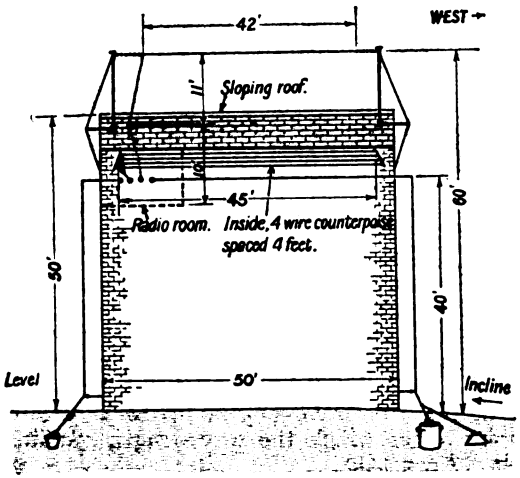

Fig. 2.

power, by merely touching the A.T.I. If you touch the wire at the voltage node, you will *not* see a small jet of smoke!

At 6TM seven "earthed" bodies are employed as well as the counterpoise. These are a buried bucket (minus bottom) in the front garden; a buried dust bin in the back garden; the main water pipe; the gas pipe; the casing of the electric mains in the house; the casing of the land line; and finally the so-called earthed main lead itself.

The power is derived from A.C. mains, at 105 volts, 50 cycles, single phase current.

The transformer used for H.T. supply is one that was picked up second-hand for seven-and-sixpence. This was found to give results without any adaptation, although the voltage regulation was appalling. The core measured 2 ins. by $1\frac{1}{2}$ ins. in cross section. The transformer would work at .5kW for a time when required, and delivered 10 000 volts across the whole of the secondary.

The rectifiers used up to date have always been some kind of chemical rectifiers. Those now used consist of 48 cells (1 in. by 6 ins. boiling tubes), the electrodes of which are aluminium and lead clamped together as shown in Fig. 3. The aluminium ones are 6 ins. by $\frac{1}{8}$ in.; the leads 6 ins. by 1 in. and are bent round the insides of the tubes. The solution used is chemically pure ammonium phosphate—$(NH_4)_3PO_4$—dissolved in distilled water. The cells are all immersed in cold water in a sink for cooling purposes.

It is found necessary to switch on the rectifiers once every evening for about one minute, in order to keep them in working condition. If this is not done, a film of some black substance forms on the surface of the aluminium, which seems to allow current to pass equally in either direction. If the cells are left idle for a few days it is very difficult to get them back into working condition.

Rectifiers, consisting of tantalum and, say, lead, in a solution of sulphuric acid in water, would be used in preference, if the tantalum could be obtained at a reasonable price, but up to the present none has been procurable.

The smoothing is effected by means of four 1μF oil-filled condensers, and two chokes (by Ford). These condensers have stood at least 3 000 volts of pulsating D.C. —measured, not guessed; they are ex-W.D. goods. The four condensers provide absolute smoothing, and pure C.W. can be obtained, even with A.C. on the filament.

The transformer used for lighting the filaments was made as follows: a bobbin of thin wood, about 6 ins. in diameter, and with a hole of 2 ins. diameter in the centre was made (the width inside may also be 2 ins.), and then filled with soft iron wire (22 gauge) wound tightly. The whole was then immersed in paraffin wax and, after removal, allowed to cool. The wood was then stripped off, and the slab of iron wire wound with

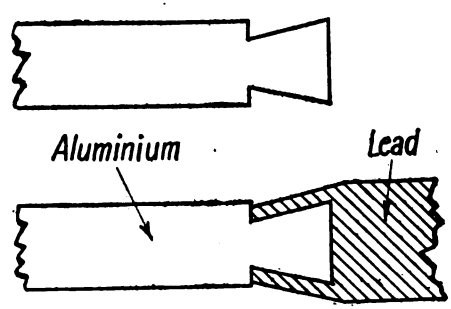

Fig. 3.

tape. The windings were then put on, using the thickest wire possible consistent with space considerations. (The winding is a little tedious but is well worth while.)

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The transformer output is shunted with a potentiometer, the centre of which is connected to the appropriate position on the A.T.I., etc. The two halves of the potentiometer must, of course, be shunted by condensers to pass the R.F. These condensers should be of good quality, and should be well spaced from surrounding objects. Of course, a centre tap on the secondary of the filament transformer would serve the same purpose as the potentiometer.

The transmitting valve used was a Mullard 0-250-C. This was obtained second-hand (vy) from a well-known London amateur, and was as a matter of fact the actual valve used when amateur communication between England and Canada first took place in 1923.

The transmitting inductance was made as shown in Fig. 4. Four strips of ebonite 1 in. by $\frac{1}{4}$ in. were clamped together, and holes drilled right through every $\frac{1}{4}$ or $\frac{1}{3}$ of an inch. These strips were then cut down the centre to admit the wire previously formed into a spring of cylindrical shape.

Lastly the strips were screwed together.

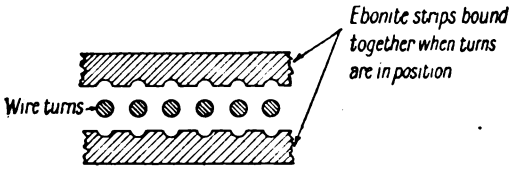

Fig. 4.

This inductance is held suspended in the air by thick string, and is thus securely fixed 18 ins. from all surrounding objects. Although the appearance is not all that could be desired, the dielectric losses must be very low.

The photo reproduced on page 721 shows a general view of the station, but was taken after several changes not described above had been made. The power valve (the 0-250-C) is shown on the right, just below the A.T.I.

In the centre is the H.T. transformer, below it, on the floor, are the rectifiers, not shown in the sink, to the right of the transformer are the smoothing condensers, and in front of these a choke.

Below the valve is the filament voltmeter, the rheostat being on the table just below the aerial ammeter. The keying relay and the grid tuning condenser are on the extreme right. The grid coil cannot easily be seen, but is slipped into the right hand of the A.T.I., immediately above the "bottle" grid leak.

Just below the inductance is the anode stopping condenser, in a jam jar, oil-filled. The aerial ammeter is seen on another jar just below to the left.

On the left is the high wave receiver, 15 metres upwards, and on the right, under the table, is the low wave set. (This is the same as that described recently by G2VW in E.W. & W.E.)

The circuit which has given the best results has been the reverse feed back shown in Fig. 5. If the grid coil is coupled to the A.T.I. in the opposite direction from the orthodox, some remarkable results are obtained: the aerial current is the same as usual, after careful adjustment, and the range seems to be the same as with the standard arrangement; but whereas, in the usual way, increasing the number of turns in the aerial coil results in increase of wave-length, here this increase of A.T.I. produces a decrease of wave-length, up to a certain point, after which the wave-length remains almost constant.

A definite point is found where the aerial current is a maximum: usually 10 turns 8 ins. diameter are used between aerial and earth system when working without a series condenser, on 95 meters, while under similar conditions, using the standard arrangement, only $1\frac{3}{4}$ turns are required.

The grid coil is tuned by a .000 2 condenser, and a vernier condenser is shunted across the plate coil for final adjustment.

The grid-leak consists of two lead wires, one in a bottle of water and the other in a capillary tube in the bottle. This leak gives good results except when a bubble of hydrogen leaves the electrode accompanied by a slight change of power.

As shunt H.T. supply is used, an anode stopping condenser is required. At first this condenser was always giving trouble by breaking down, with consequent shorting of the H.T. The present one, however, is a "double spaced" variable condenser, the fixed plates being $\frac{1}{4}$ in. apart. This is immersed in condenser oil in a jam jar.

Keying is effected by breaking the connection between the grid coil and filament.

It is noteworthy that direct connection to the aerial is used, as this gives the best range, and the note has always been reported as dead steady. No series A.T.C. is used.

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Although an aerial current of several amps is obtained, this is due to the unusual aerial system, rather than to any abnormal efficiency.

15 metres, and another from about 6 down to about 2.5. The front of the panel of the high-wave set is lined with lead to prevent capacity effects.

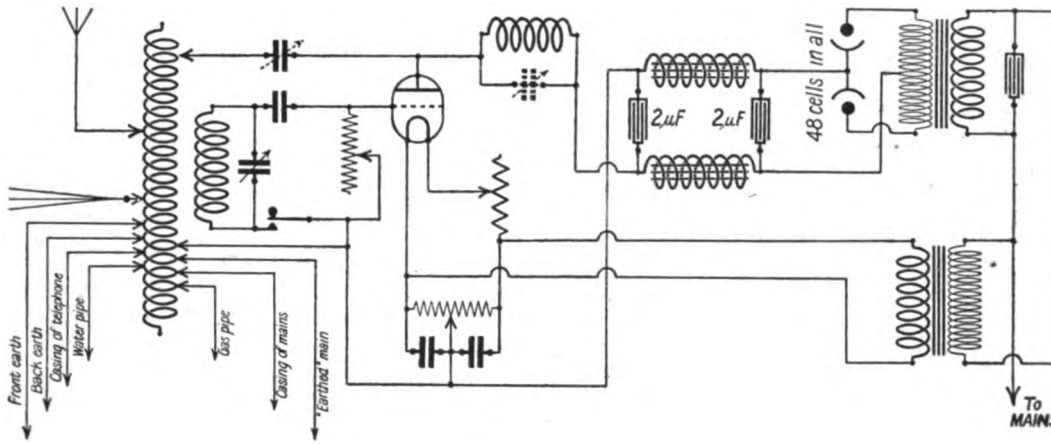

Fig. 5.

Almost all work has been done on, or around, 100 metres; little has been done recently on 200 metres, but some successful tests have been made on about 3 metres.

Concerning the results obtained on 100 metres, no station *had* been worked at over 1 500 miles until 26th October, 1924, when Z4AG was called and a reply was received—Z4AG calling U6TQ or U6TMA, which was probably a misreading of G6TM. However, on 29th October, 1924, an N.Z. call at 6.15 was answered by Z4AA, who was worked till QSS set in—about 1¼ hours. Every message each way was received perfectly, and he was worked again the next morning. As we were "signing off" 4AA said: "You are the best station in G.B.," but, of course after that, the rectifiers at 6TM immediately began to give trouble, and the A.T.I. collapsed, and ever since some cause or other has prevented reliable N.Z. working.

Several local receivers report that two Australians have been heard calling G6TM, but nothing definite has yet been done. Several Americans have been worked, but only one serious attempt has been made to work U.S.A. stations. This was on 28th November, 1924, when eight were worked; also 31 cards relating to the occasion have been received.

The receiver at 6TM is merely a detector and 1 L.F. This set goes down to about

The rectifiers previously used for accumulator charging were of the rotary type, but more recently a chemical one, designed as shown in Fig 6, has been employed. This gives excellent results if reasonably used.

A number of Yank 6's have been logged, including one remarkable freak (since confirmed), namely, the reception in January, 1924, of U6XAD, on 200 metres, using one valve, a Telefunken of prehistoric and idiotic design, with anode and grid in the form of flat plates.

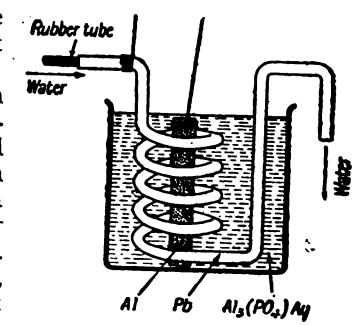

Fig. 6.

Apart from freaks, however, 4Z's and 4A's have been logged, and a large number of other Yanks.

For instance, on the last occasion, 150 different Yanks were logged.

In conclusion it may be stated that the station is being entirely rebuilt, and hopes to be on the air again by the time this article appears.

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Measurements with the Numans Oscillator.

By K. C. van Ryn. [R201·22

This article describes methods of making accurate measurements of capacity, inductance and wave-length without the use of expensive apparatus.

As this oscillator, described in E.W. & W.E. for December, 1924, has the property of bringing into oscillation any closed circuit connected to it, it is obvious that an ordinary buzzer-wavemeter can be converted into an oscillating wavemeter by connecting it to this oscillator. If one possesses a commercial wavemeter it can thus be used for the longer wave-lengths while extra coils can be inserted into the oscillator for the shortest waves, down to ten metres. The curves of the ordinary wavemeter, however, will have to be corrected.

Capacity Measurements.

The first thing to do is to calibrate the variable condenser of the oscillator. A small accurately calibrated fixed condenser of about 0.1 of the capacity of the condenser on the oscillator should be obtained: it can be got, usually, by paying a few pence extra. To calibrate the variable condenser proceed as follows: Set up the oscillator, and near it a simple single valve reaction receiver. Insert a coil in the oscillator, set the variable condenser at zero, and tune the receiver to zero beat. Shunt the variable with the known fixed condenser, and tune the receiver condenser till the beat-note reappears. By alternately enlarging the receiver and oscillator capacity some ten points can be found which will be almost on a straight line, though the zero and maximum capacities will probably deviate slightly from it. (For convenience in capacity measurements it is advisable to use an ordinary condenser in the oscillator, with semi-circular plates, and not one of the "square law" type.) The absolute error of the fixed condenser is of course multiplied by ten, but the relative error will not alter greatly.

To measure with the oscillator a capacity smaller than that of its variable condenser, set this near its maximum position, listen for the beat-note, shunt it with the unknown capacity, and turn the knob back till the note reappears. The unknown capacity can now be read off from the graph. Larger capacities can be measured by first calibrating a larger variable condenser or by shunting the oscillator condenser with a number of fixed condensers of known capacity.

The zero capacity of the oscillator can be found by the two following methods:—

(A) The first method makes use of two absolutely identical coils, for example, two 200 turn honeycomb coils. Two coils can be matched with the Numans oscillator by listening to the beat-note in a receiver while the coils are plugged into the oscillator. Remove windings from one of them till the wave-lengths produced by each are equal. An amazing degree of accuracy can thus be obtained, though it is not essential for this purpose. (The value of the inductance plays no part in this measurement, only the self-capacity.) Now insert one of the coils in the oscillator and listen for the beat-note. Then

$$\lambda = 1\,885\sqrt{(C_1 + C_c + C_g)L} \quad .. \quad (1)$$

where C_1 is the capacity of the oscillator condenser, C_c is the self-capacity of the coil and C_g is the self-capacity of the oscillator. If we have set the oscillator condenser near the upper end of its scale (say 160°) we shall find the second harmonic in the neighbourhood of 30° (the second harmonic gives the strongest beat-note after the actual wave-length itself). We can now write

$$\lambda/2 = 1\,885\sqrt{(C_2 + C_c + C_g)L} \quad .. \quad (2)$$

whence

$$C_c + C_g = \frac{C_1 - 4C_2}{3} \quad .. \quad (3)$$

C_1 and C_2 can be read from the graph.

We now make use of the second similar coil which we shunt in parallel with the first one and repeat. Then

$$\lambda' = 1\,885\sqrt{(C_3 + 2C_c + C_g)L'} \quad .. \quad (4)$$

$$\lambda'/2 = 1\,885\sqrt{(C_4 + 2C_c + C_g)L'} \quad .. \quad (5)$$

(3), (4) and (5) give us

$$C_g = \frac{2C_1 - 8C_2 - C_3 + 4C_4}{3} \quad .. \quad (6)$$

Once the zero capacity of the oscillator has been measured in this way, we can easily

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find the self-capacity of any coil from the equation (3).

(B) If the wave-length calibration of the oscillator is available (see below) we can dispense with the second coil. Place the coil to be measured near the oscillating wavemeter. When the oscillator (oscillating strongly) passes the wave-length of the open circuited coil, a click will be heard in the oscillator, and another one on turning the condenser back again. By carefully loosening the coupling, the two clicks may be brought together and the point where they occur indicates the wave-length to which the open coil is tuned. We can then write

$$\lambda = 1\ 885\sqrt{(C_c L)} \quad .. \quad .. (1)$$

Now shunt the open coil with a condenser of known capacity and repeat. Then

$$\lambda' = 1\ 885\sqrt{(C + C_c)L} \quad .. \quad (2)$$

(1) and (2) gives us C_c and L in $\mu\mu$F and μH, if we express λ, C and L respectively in metres, micro-microfarads and microhenries. The C_g is then found by plugging the coil into the oscillator with its condenser at zero. If we measure the resulting wave-length, we have

$$\lambda'' = 1\ 885\sqrt{(C_g + C_c)L} \quad .. \quad (3)$$

The equations (1), (2) and (3) then give us the capacity C_g. (Some doubt may arise as to whether the capacity C_c thus measured is the real self-capacity. In any case it is the value we may substitute for it.)

Inductance Measurements.

Shunt the inductance to be measured with a known capacity C and measure the wave-length of this combination by the "click" method as shown above. Then

$$\lambda = 1\ 885\sqrt{(C + C_c)L} \quad .. \quad (1)$$

If C_c is small in comparison with C, which is mostly the case, it can be neglected and L can be found from (1) directly. For very accurate measurement we must first determine C_c.

An idea of the comparative inductances and capacities of telephone and transformer windings can easily be obtained by plugging them into the oscillator and comparing the resulting audio frequency notes. By increasing the parallel capacity until the frequency is halved (distinguished with the ear or a tuning fork), the value of the self-capacity can be determined.

The Numans oscillator can easily produce frequencies as low as 25 per second. The telephone in this case should not be plugged into the anode circuit, but connected by one lead only to the winding under measurement. (Otherwise a "mush" will be heard instead of a clear note.)

Aerial Measurements.

To find the fundamental wave-length of an aerial system proceed in the usual way, *i.e.*, connect a buzzer or an induction coil in the aerial circuit and listen on the oscillator for the emitted wave. To obtain a sharp note the wavemeter should not oscillate.

The actual capacity of an aerial system can be determined simply by measuring its capacity with the oscillator as mentioned above. Plug a coil in the oscillator, set its condenser near the maximum, shunt the coil across the aerial circuit (earth to the filament side of the coil), and turn the condenser back until the apparatus is again tuned to the original wave-length. The aerial capacity varies with the wave-length but a fair idea of its value (above the fundamental) can be obtained in this way. The inductance of the aerial is in parallel with the coil but can safely be neglected if a large inductance, say a honeycomb coil of not less than 200 turns, is used.

Wave-length Calibration of the Oscillator.

The wave-length calibration of the oscillator is an important matter, as the oscillator is probably used most frequently for wave-length measurements. A very high degree of accuracy is obtainable once the calibration has been accurately performed. To do this we may proceed in two ways:—

(A) By the use of a calibration signal. It is possible by the use of harmonics to make a complete series of curves (say from 10 to 30 000 metres), providing that one wave-length is accurately known.

(B). By the use of a standard wavemeter.

The following practical hints may be of use. If a regenerative receiver or a Numans oscillator oscillates, there will be produced, besides the fundamental wave-length, harmonics on 1/2, 1/3, 1/4, 1/5, 1/6, 1/7, . . . etc., of the wave-length. The strength of these gradually decrease in the above order. It will be assumed here that the first harmonic

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is the wave itself and the second one-half of the wave-length. On this assumption the sixth harmonic has 1/6 of the wave-length and not 1/5. It is to be remembered that when listening, for example, to the fundamental with the tuning condenser at the maximum (100 divisions), the second harmonic will not be found at 25 divisions but somewhat lower ($\frac{1}{4}$ of the total capacity) owing to the zero capacity of the condenser. With a very small condenser it may therefore be necessary to plug in a new coil in order to find the second harmonic.

As mentioned above one can force the oscillator *or* the regenerative receiver to produce the harmonics. The valve of the former should therefore be given ample high-tension and the filament should be as bright as possible; the latter in addition requires a strong feed-back coupling. *One* of the two should be made to produce the harmonics, not both, otherwise all the harmonics of the one will interfere with all those of the other. Near the fundamental, especially on short wave-lengths, the coupling between the receiver and the oscillator should be made very loose, otherwise the note will be wiped out and passed without notice. With a single valve, the harmonics of an oscillator or an oscillating receiver can be distinguished until about the tenth; with a two valve note magnifier added, up to the thirtieth harmonic can easily be heard.

Dealing now with the actual calibration, we will assume that an oscillator produces a wave of 1 000 metres wave-length. The harmonics produced will be: 500, 333, 250, 200, 167, 143, 125, 111, 100, 91, 83, 77, 71.5, 66.5, 62.5, 59, 55.5, 52.5, 50, 47.5, 45.5, 43.5, 42, 40, 38.5, 37.1, 35.7, 34.5, 33.3, . . . metres. It will be noted that at the higher frequencies the harmonics are more crowded and therefore a curve can more easily be drawn. Therefore, to draw a curve ranging from 100 to 240 metres, we set the oscillator which is producing harmonics at 2 400 metres, for a curve from 60 to 140 metres we use the harmonics of a 1 600 metre wave and for a curve from 42 to 100 metres we use a wave-length of 800 metres.

As mentioned above, we can make either the receiver or the oscillator produce the harmonics. Assume that we have an accurate calibration at 600 metres on the oscillator. To proceed *upwards* we can make the oscillator produce the harmonics, and listen in the receiver for the beat-notes. We then obtain calibrated points on the oscillator at 1 200, 1 800, 2 400, 3 000, 3 600, 4 200 metres. To calibrate *downwards* we make the *receiver* produce the harmonics, the fundamental of the oscillator beating with these. We then obtain calibrations at 300, 200, 150, 120, 100, 86, . . . metres.

We will now give an example of the procedure for obtaining a calibrated curve from 100 to 240 metres. For this purpose we may use a coil of 7 cm. diameter wound with 39 turns of No. 19 D.C.C. wire.

Assume that we have obtained, by the use of an accurate wavemeter, a curve for the oscillator, *e.g.*, from 300 to 550 metres. With the aid of this we set our receiver at 400 metres, then plug the above coil in the oscillator and take the reading of the oscillator condenser for a wave-length of 200 metres, *i.e.*, the first harmonic of the receiver. As mentioned before, for a 100 to 240 metre curve we will make use of the harmonics of the receiver when it oscillates at 2 400 metres. We therefore set the receiver at what we think will be 2 400 metres (*i.e.*, a weak beat-note) and leave it there. To make sure that we are really on a wave-length of 2 400 metres and not on 1 600, 2 000, or 2 800 metres, we again plug the calibrated coil into the oscillator and note the harmonics that are produced with the receiver set at what we suppose is 2 400 metres. We can then make a table such as that following.

Reading of oscillator condenser.	Wave-length of oscillator.	Degree of harmonic.	Wave-length of receiver.
7.7	299.0	8	2 392
18.2	343.0	7	2 401
34.6	400.0	6	2 400
62.0	480.0	5	2 400
		Average	2 398 m.

The third column gives the degree of the harmonic; at 7.7 divisions we strike the eighth harmonic of the receiver and so on. We can now safely assume that the receiver is tuned to 2 400 metres. (The accuracy here is better than 1/3 per cent.) We now once more plug the coil to be calibrated in the oscillator and note the condenser reading every time we hear a beat-note due to the fundamental of the oscillator interfering with a harmonic of the receiver.

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For *one* condenser setting we already know the degree of the harmonic, and from this, going up and down the scale, we may make a table such as that shown in the next column.

Care must be taken not to miss any beat-note, because then the degree of the harmonic will become incorrect. The points should lie on a smooth curve and the distance between the points should increase proportionally, which serves as a check. If desired more points can be found at the top of the curve by repeating the measurement with, for example, a 1 600 metres wave.

In conclusion, I would like to urge the reader not to be discouraged by the somewhat lengthy description of the method of getting the calibration and of making the measurements. Once the oscillator has been calibrated and the self-capacity and capacity curve known, the instrument will soon become, to the real experimenter, a most valuable piece of apparatus.

Reading of oscillator condenser.	Degree of harmonic.	Wave-length of the oscillator.
98.8	10	240.0
79.2	11	218.0
64.5	12	200.0
53.0	13	184.5
43.5	14	171.5
36.0	15	160.0
30.0	16	150.0
25.3	17	141.2
21.0	18	133.3
17.5	19	126.3
14.5	20	120.0
11.8	21	114.2
10.0	22	109.2

Further Valve Tests. [R333·009

Below we describe four more valves which have recently been tested in our laboratory—the D.F.A.4 by the Mullard Radio Valve Co., the R and B.6 by the British Thomson-Houston Co., and the "C & S" by Messrs. Craik & Smith.

The D.F.A.4.

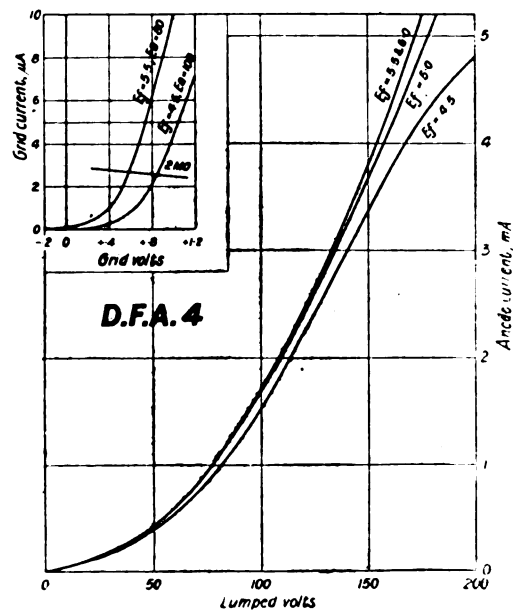
THIS valve, as our readers may remember, was first reported upon on p. 367 of our March, 1925, issue. In this case we found the voltage amplification to vary from 10.5 to 15.0, the anode impedance rising from 13 000 to 27 000 ohms. The power amplification was in the neighbourhood of 9.0. Both the voltage amplification and the power amplification were thus rather low for this type of valve.

The Mullard Radio Valve Co., Ltd., the makers of the valve, on seeing the report, suggested that we had received a specimen of unusually low μ and accordingly they sent us another of these valves for a further examination. This we have now tested, and find that the second sample is distinctly different. The filament voltage and current are exactly as before, namely, 4.5V, .17A; 5.0V, .18A; 5.5V, .19A; and 6.0V, .20A. The saturation plate current is somewhat greater, rising to 35mA at 6.0V on the filament. The anode impedance is approximately the same as that of the previous specimen, but the μ is much higher, rising to 21.8. The power amplification is also much higher, and so is the filament efficiency.

D.F.A.4.

Fil. Volts. E_f	Fil. Cur. I_f	Sat. Plate Cur. I_s	Anode Impedance. R_a	Voltage Ampli. μ	Power Ampli. P $\left(=\frac{1000\mu^2}{R_a}\right)$	Filament Efficiency. F $\left(=\frac{I_s}{\text{Watts.}}\right)$
4.5	.17	7	27 000	19	13	9.2
5.0	.18	13	20 600	20.6	20	14.5
5.5	.19	22	18 000*	21.6*	26	21.0
6.0	.20	35	17 500*	21.8*	27	29.0

* At 200V.



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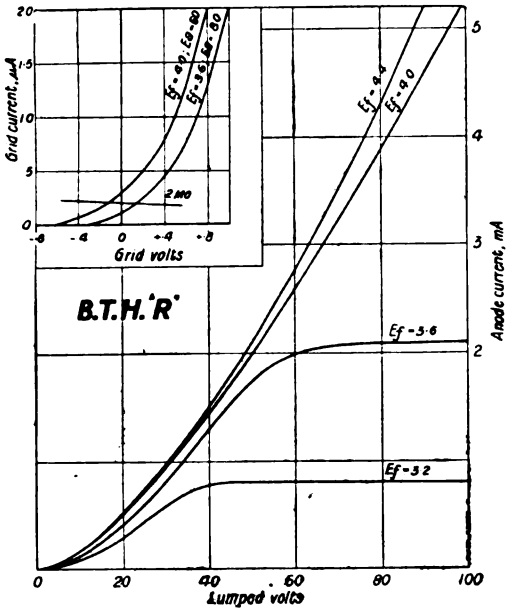
In fact, the second valve tested falls into line with the other members of its class (625b) though it is quite an open matter whether it is a *better* valve, even for use in a resistance-coupled amplifier.



The curves obtained with the second valve are reproduced herewith. It is to be noticed that no great advantage is secured by increasing the filament voltage above 5.5. In fact, the lower portions of the curves for 5.5 and 6.0V are practically identical.

The price of the valve is now 22s. 6d.

The B.T.-H. "R."

This valve is a bright emitter of the R type, which still finds favour with many users, in spite of the growing popularity of the dull-emitter. It is rated by the makers, the British Thomson-Houston Co., Ltd., at 4.0V, 0.7A for the filament; plate voltage (maximum) 100. It thus really belongs to our "460" (or, rather, "470") class. The electrodes, which are of the usual form, are mounted vertically, and the bulb of the valve is of the tapering, "pipless" type.

With filament voltages of 3.2, 3.6, 4.0 and 4.4, the filament current of the valve varied from 0.59 to 0.7 amp. Thus the current consumption is somewhat less than that mentioned by the makers.

The saturation anode current rises from .8 to 17.0mA. The current value at 4.0 volts on the filament, 6.5mA, is a trifle low for a valve of its class. The impedance is roughly normal, but the magnification μ is very low, being in the region of 3. An average value for valves of this type is 7. As a consequence, the power amplification, which is proportional to $\mu^2 R_a$, is also rather low. The filament efficiency is normal.

From the curves obtained, it can be seen that the valve requires the full 4.0V on the filament for use as an amplifier. At about 60 lumped volts, the curves for 4.0 and 4.4 filament volts begin to straighten out nicely. The valve will probably function best as a first stage L.F. amplifier (transformer coupled), since for H.F. amplification and resistance-coupled L.F. amplification a valve of fairly high μ is desirable.

From the grid-current curves it will be seen that the valve will serve as a reasonably good detector using the usual 2MO grid-leak.

We think that the valve we tested may have been a rather abnormal one as regards the low amplification factor, since in other respects it was, comparatively speaking, normal.

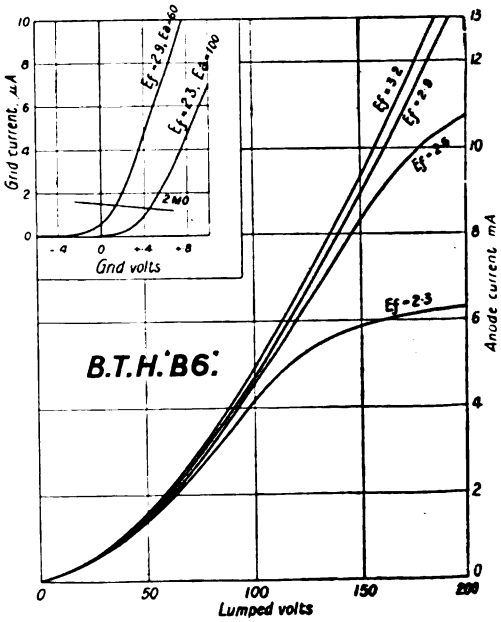
The price of the valve is 8s.

B.T.-H. "R."

Fil. Volts. E_f	Fil. Cur. I_f	Sat. Plate Cur. I_s	Anode Impedance. R_a	Voltage Ampli. μ	Power Ampli. $P = \frac{1000\mu^2}{R_a}$	Filament Efficiency. $F = \frac{I_s}{\text{Watts.}}$
3.2	.59	.8	83 000	3.3	.33	.42
3.6	.62	2.1	20 000	2.7	.35	1.0
4.0	.66	6.5	14 000	2.24	.36	2.4
4.4	.70	17.0	9.500	3.5	1.28	5.5

The B.T.-H. B6.

This is a 3-volt dull-emitter power valve, with a filament rating of 3.0V, 0.12A. It therefore belongs to our "312" class, and is intended for use in sets employing for the other stages valves of the popular "306" type.



Actually at filament voltages of 2.3, 2.6, 2.9 and 3.2, the currents varied from .10 to .13 amp, while the saturation plate current rose to 28mA at 3.2V:

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hence the valve is capable of dealing with plenty of power. The impedance was in the region of 12 000O, the amplification factor (μ) remaining approximately constant at 6.7, which is quite a

B.T.-H. B6.

Fil. Volts. E_f	Fil. Cur. I_f	Sat. Plate Cur. I_s	Anode Imped-ance. R_a	Voltage Ampli. μ	Power Ampli. P $\left(=\frac{1\,000\mu^2}{R_a}\right)$	Filament Efficiency. F $\left(=\frac{I_s}{\text{Watts.}}\right)$
2.3	.10	7	16 000	6.4	2.6	30
2.6	.11	13	13 500	6.7	3.4	45
2.9	.12	20	11 000	6.7	3.9	57
3.2	.13	28	10 000	6.7	4.4	70

normal value. The filament efficiency is one of the highest yet found.

From the anode current curves it will be seen that both those for 2.9V and 3.2V on the filament are excellent for amplification purposes. As, however, no great gain in μ or power amplification is obtained at the higher voltage, it is probably best to use only 2.9V on the filament, resulting in an increase in the length of life of the valve.

For small loud-speaker work, the amplitude on the grid may be 5V. From the curves, the lumped voltage should not be less than about 125 volts for distortionless results. If the grid is biased to — 5 volts, the anode voltage will thus have to be $125+(5\times7)=160$ (assuming $\mu=7$).

An inspection of the grid-current curves shows that the valve has good possibilities as a detector, as the bend in the curves is quite sharp. For best results a leak of rather higher resistance than 2MO—say 4MO—will probably prove advantageous.

The "C and S" Dull Emitter.

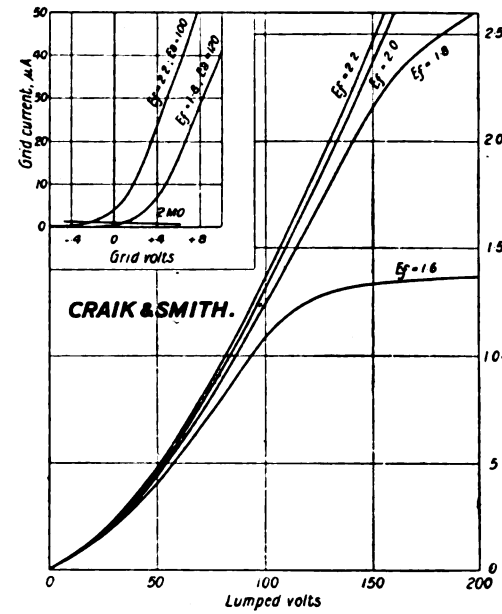
A rather unusual valve is that supplied by Messrs. Craik and Smith, of Allen Street, London, E.C.1.

This has a rather squat, tubular bulb and the electrodes are small in size and arranged horizontally. The grid is peculiar in that it consists of thin and narrow strips of metal arranged in cylindrical formation, instead of the more familiar wire spiral.

Tested at filament voltages of 1.6, 1.8, 2.0 and 2.2 the filament currents ranged from .20 to .23. It must thus be placed in the "235" class, though actually a "220" classification fits it better. The saturation current, which is 10mA at 2.2V on the filament, is lower than that of the average "235" class valve, while the impedance is much greater, varying from 70 000 to 37 000O. The voltage amplification is also abnormally high, being about 15. The power amplification and the filament efficiency are roughly normal for this class.

The valve might almost be said to be a "220b," or high magnification, valve, though, owing to the high impedance, the power amplification is not as great as would be expected in this type of valve.

Owing to its high magnification and to the fact that it cannot deal with a very large amount of



power, the valve, if used as an amplifier, should be placed preferably in the H.F. stage. Here it should work very well, with a fairly high plate voltage.

"C & S."

Fil. Volts. E_f	Fil. Cur. I_f	Sat. Plate Cur. I_s	Anode Imped-ance. R_a	Voltage Ampli. μ	Power Ampli. P $\left(=\frac{1\,000\mu^2}{R_a}\right)$	Filament Efficiency. F $\left(=\frac{I_s}{\text{Watts.}}\right)$
1.6	.20	1.5	70 000	14	2.8	4.7
1.8	.21	3.5	54 000	15	4.2	9.0
2.0	.22	7.5	39 000	14	5.2	16.5
2.2	.23	10.0	37 000	16	6.9	20.0

As a detector, the valve should work extremely well, as will be seen from the gird current curves. Here again the plate voltage must be high (at least 100 volts), owing to the high impedance of the valve. A 1MO or 2MO leak should prove quite satisfactory.

The price of the valve (12s.) is quite low, and this coupled with the fact that the current consumption is also below the average of its class, should make the valve worth trying.

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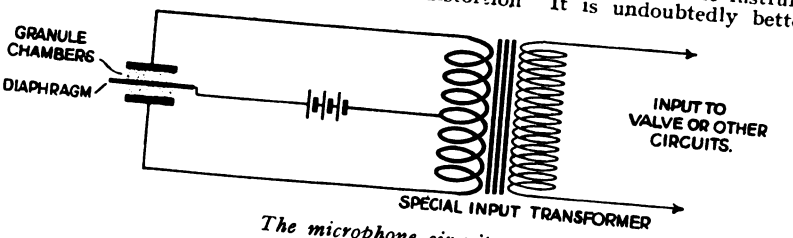
Apparatus Tested.

The Brown Differential Microphone.

[R009

EXPERIMENTERS who are interested in telephony are familiar with the difficulty of obtaining a good microphone at a reasonable price. Messrs. S. G. Brown have submitted to us a specimen of their differential hand microphone. Before commenting upon this particular microphone it may be best briefly to summarise the connections and advantages of such differential or "push-pull" arrangements.

The response of a carbon microphone is not a linear function of the pressure applied to the diaphragm, that is to say, the variation of resistance with pressure is not quite the same at different absolute pressures. This gives rise to a form of distortion similar to that produced by an L.F. amplifying valve operating over a curved portion of its characteristic. The object of the push-pull arrangements of valves or microphones is to eliminate this form of distortion. The circuit used in the case of microphones is given herewith. The microphone has two distinct granule chambers and when the diaphragm moves one is under compression while the other undergoes expansion, and *vice versa*. The resistance variations in the two granule chambers are in opposite phases, so that a differential input transformer is necessary to superimpose their undistorted components in the same phase. This transformer has simply a mid-tapped primary and an ordinary secondary winding. Without entering further into the theory here we can state that this arrangement eliminates such current variations as are proportional to the square and other even powers of the amplitude of the displacement of the diaphragm. If the full advantage of the system is to be realised it is essential that the two microphone chambers should have exactly the same electrical characteristics.



The microphone circuit.

The Brown double-button microphone which we have tested is of the hand type and is exceptionally light and convenient, the case being of aluminium and similar in size and shape to the Brown telephone earpiece. The combined mouthpiece and screw-cap is of ebonite as is also the handle. There are three leads from the microphone; one is distinguished by green binding at the end and is the connection common to both halves while the other two leads are the "outers." The diaphragm which actuates the microphone is a light aluminium cone such as is used in the "A"-type receivers.

The microphone is meant to work off a 4 or 6-volt battery. Its mean resistance is rather variable and the currents passed are not high. Using 6 volts we found that the total current taken by both halves varied between 50 and 200 milliamperes. Although the makers carefully adjusted the two halves to have equal resistances before submitting the microphone to us, we find that the two halves do not stay properly balanced, so that the advantages of the push-pull connections are hardly fully realised. The quality of speech given by the microphone is, however, very good, and mechanical resonance in the body of the instrument is practically absent. It is undoubtedly better than the generality of microphones, such as the solid-back type, which are available to amateur experimenters and others. We have tried it on our choke-control transmitter, and, to be quite candid, have received estimates of the quality of speech tending to show that the quality obtainable by using one-half alone as an ordinary microphone is as good as that obtained by using both halves in the push-pull manner. The double microphone doubtless has the advantage, however, over the ordinary type that it is less likely to pack or become inactive when held in certain positions. The microphone is singularly free from hissing and crackling sounds.

As already indicated, the microphone does not handle a large current, but it should be remembered that good speech quality in microphones cannot usually be expected to be accompanied by high current carrying capacity. The serious worker will not object to using a stage or so of L.F. amplification if this will permit the use of a good microphone. With regard to the differential microphone transformer supplied, we do not consider that this is of the best possible design for controlling the grid of a valve. The step-up ratio from primary to secondary

The microphone and its special transformer.

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is much too low. The grid input of a properly biased valve amplifier takes practically no load from the secondary, which may therefore have a large number of turns. We obtained much better results by using the secondary from an ignition coil. It also seems rather a makeshift plan to use two ordinary telephone transformers simply screwed down side by side on a common baseboard instead of winding a special differential transformer over one core.

We understand that the microphone was not originally put on the market for amateur use, which may account for the rather high price of £11 for the outfit.

E. H. R.

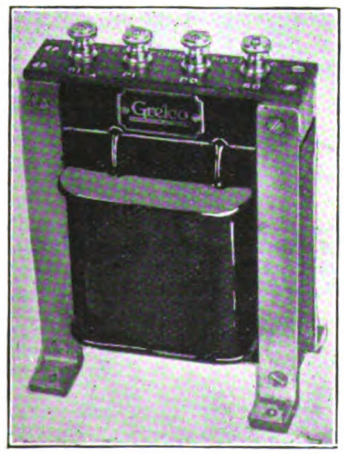
Some "Grelco" Products.

The Grafton Electric Co., of 54, Grafton Street, W.1, have recently produced a range of excellent L.F. transformers together with an L.F. choke, bearing the name "Grelco." Samples of these were sent to us for test, and the results obtained will be of unusual interest to our readers. The transformers are made in three ratios, 6 to 1, 4 to 1 and 2 to 1.

With regard to the first two, excellent results were obtained, and they can be highly recommended. So good were they that instead of comparing them with our usual standard (a first-class commercial instrument) we used the one particular transformer which has hitherto been the best which we have handled. Against this, the "Grelco" 6 to 1 and 4 to 1 instruments showed up very well.

Comparing transformers of the same ratio, there was no appreciable difference in the strength. In tone a slight difference could be detected, though it would be unfair to say that one was better than the other in this respect.

The low ratio transformer (2 to 1) did not give such good results. The volume fell off, as might be expected, owing to the low ratio; but, in addition, the tone was noticeably higher. The makers have possibly reduced the number of turns on the secondary in this case.



The "Grelco" transformer.

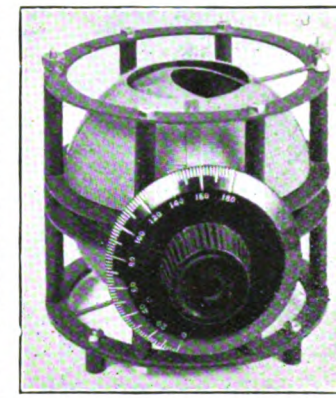
The choke, though not actually tested, should be quite efficient, since the number of turns is 30 000 and the iron core is similar to those of the transformers.

As will be seen from the illustration, the transformers have very generous windings and large cores. At the top is an ebonite strip on which are mounted the terminals. The size of the instrument is necessarily large, the measurements being 3½ ins. wide by 2½ ins. thick by 5 ins high, but this disadvantage always has to be faced where extreme efficiency is desired.

The prices are £1 10s. each for the transformers and £1 5s. for the choke.

Some New Variometers.

Messrs. Varic, Limited, of Castle Hill, Bedford, are making some neat and efficient air-spaced variometers bearing the name "Varic." These are of the ball type, and are made in two patterns—for panel mounting and for table mounting. The latter can also be used for panel mounting if desired. The coils, which are wound with a heavy gauge wire (about 20 s.w.g.), are self-supporting, so that dielectric losses due to the usual former are avoided. The clearance between the coils is quite small, and hence a good range of inductance is to be expected.



The "S.T." type of "Varie" variometer.

The spindle of the rotor, which is in two parts, is ¼ in. in diameter, and efficient contact to it is made by two spring bearings. The dial and knob, which are moulded together, are attached to the spindle by a set screw. Terminals are provided for making contact to the variometer.

The table mounting type (which we illustrate) is made in two sizes—for wave-lengths of 250-650 metres and 580-2 320 metres. We tested one of the former. The results obtained were very good. The minimum inductance was 35μH (microhenries), and the maximum was 338μH. The self-capacity ranged from 10μμH to 25μμF, and the resistance at about the middle of the range was 8.4 ohms, giving a power factor of approximately .016, which is quite good for this type of tuner. There is no doubt that these variometers are some of the most efficient we have yet tested.

One small defect was noticed, namely, that it was possible to push the spindle in and out for about 1/16 in., thus varying the position of the rotor relatively to that of the stator, which might cause trouble when accurate tuning was required. This is, however, not a very serious fault, and, in any case, it can be easily rectified.

We are of the opinion that the wave-length range claimed by the makers is rather conservative—we should imagine that the variometer tested would tune down to well below 250 metres with an average P.M.G. aerial.

Although we did not test the larger model, it is similarly made, and should prove equally efficient.

The prices are :—

	s.	d.
Type S.P. (250-650 metres, panel mounting)	10	0
,, S.T. (ditto, table or panel mounting)	12	6
,, L.T. (580-2 320 metres, table or panel mounting)	15	0

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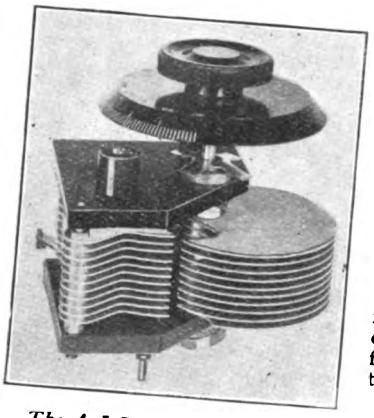
The "A.J.S." Variable Condenser.

Messrs. A. J. Stevens & Co., Ltd., of Wolverhampton, have recently sent us one of their special variable condensers for test and report. This, as can be seen from our illustration, is provided with stout ebonite end-plates, and the spindle of the moving plates has substantial adjustable metal bearings. The condenser is not intended for one-hole fixing, two screws with ebonite distance-pieces being supplied for mounting. There is also a neat friction washer which is placed between the dial and the panel. The dial and knob are well finished, the former being engraved from 0 degs. to 180 degs.



The A.J.S. condenser. Note the curiously shaped plates.

Positive connection to the moving plates is made by means of a spiral of brass strip. On handling the condenser, one realises that it is a sound job from the mechanical point of view. The plates, which are of aluminium, are curiously shaped in order to give a "square law" effect, as will be gathered from the illustration.

On test the condenser gave very good results. The particular one we have is rated as .000 5μF maximum, and we found it to be .000 532μF. The minimum capacity was exceptionally low, being only .000 007μF. The high frequency resistance was also very low. These facts, coupled with the mechanical efficiency, make the condenser a very satisfactory instrument.

The condenser is made with maximum capacities of .000 2μF, .000 3μF, .000 5μF and .001μF, the prices being 10s. 6d., 11s. 6d., 12s. 6d., and 17s. 6d. respectively.

Two Crystal Detectors.

The Harlie Detector.

This is a most interesting little component, out of the usual run of galena detectors. As will be seen from our sketch, the crystal is a special one moulded into a cylindrical shape, and the contact point can be adjusted entirely without skill.

When we started to test it, we were quite puzzled at first by an unusual phenomenon: most of the points tried rectified very well, but some passed the current one way and some the other, whereas in the usual galena the current almost always goes from crystal to point.

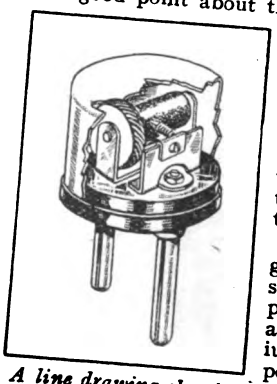
On trying five points taken entirely at random, we got an average output power of 32 per cent. of the input, and an average H.F. resistance of about 20 000 ohms—rather on the high side; all these figures were obtained with an input voltage of .5, at a frequency corresponding to 377 metres.

Next we found a good point and applied various voltages from 1 to .1, getting an efficiency of 69 per cent. at the high voltage and 16 at the low. Taken together, these figures show an excellent performance, and another point in its favour is the ease of handling. It is sold by Harlie Bros., 183, Dalston Lane, Hackney, E.8, at 5s. 6d.

The Ledion Crystal.

This is a very interesting crystal, although it is offered as an ordinary galena. The outstanding point is the exceptional output current given. The efficiency (*i.e.*, ratio of input power to output power) is first-class, though not extraordinary—it was about 50 per cent. on most of the points tested—but the H.F. resistance was only about 4 000 ohms.

A good point about the crystal is the fact that it is almost equally sensitive all over; of five points tested at .5 volt, the worst gave 44 per cent. and the best 52 per cent. efficiency. Also, the efficiency is maintained better at low input than is usual with this type of crystal.



A line drawing showing the construction of the "Harlie" detector.

Altogether it is a very good crystal, but it should be put across part, and not all, of the aerial coil, as otherwise it will take too much power and give flat tuning.

It is sold by Messrs. Ledion, Ltd.

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A Method of Testing the Insulation Resistance of a Condenser without a Galvanometer.

By Forbes W. Sharpley, A.M.I.E.E. **[R240**

IT occasionally happens that on endeavouring to locate a fault in the working of his receiving set a wireless experimenter will suspect one or other of his fixed, sealed condensers as being the probable cause of the trouble. However, there are comparatively few amateurs who possess a galvanometer sufficiently sensitive to show a leak even as large as 1 megohm through the dielectric of a condenser, and a smaller leak than this (*i.e.*, one of greater resistance) may make a considerable difference in the strength of received signals. On the other hand all experimenters will possess either a high or low resistance pair of telephones, and if properly used these may take the place of a galvanometer for detecting the presence of a leak and, if required, for estimating its value to some degree of accuracy.

Connect up as in Fig. 1, where *C* represents the condenser under test, *T* the telephones, *K* an ordinary morse key, and *V* a steady applied voltage (about 2 volts to commence). On closing *K* there will be a click in the telephones of a strength depending, for a given pair of telephones and a given voltage *V*, on the size of the condenser under test and on the value of the leak, if any, through it. This click will be caused

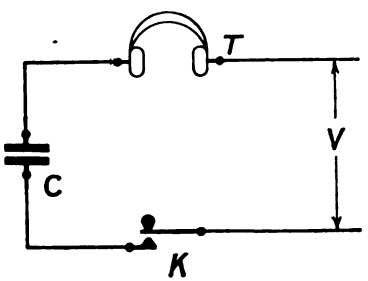

Fig. 1.

by the current, which is the sum of that flowing in to charge the condenser and that which may flow through any leak in it.

Now if the condenser be perfect, as soon as it is charged all current will cease to flow, since it will exert a back E.M.F. equal in value to *V*. On the other hand, if the condenser leaks, the current which flows on closing *K* may diminish immediately, but will never reach zero value.

This gives us the method of discovering the leak, for on opening *K* after a moment, there should be absolutely no sound in the

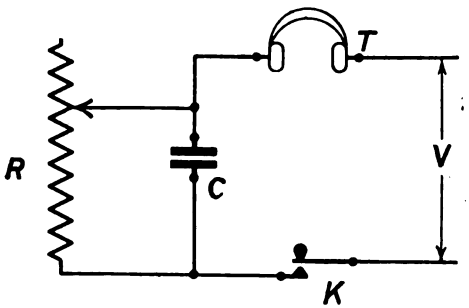

Fig. 2.

telephones if the condenser is good, while if it is faulty, there will be a second click due to the sudden cessation of the leakage current. The strength of this second click depends on the value of the leak, and will be approximately as loud as the first only if there is a complete short-circuit in the condenser; while if there is a partial leak, this click will be small compared with the first. In either case its strength depends on the value of the leak (for any given voltage) and on the size of the condenser.

The following figures will give an idea of the results which may be obtained so far as merely detecting a leak is concerned. It was impracticable to obtain condensers for testing purposes having various degrees of leakage resistances, but one or two perfectly good condensers of very high insulation resistance were tested, using an external leak connected across or in parallel with the condenser as in Fig. 2. Electrically, of course, this leak acted in exactly the same manner as an internal one would

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have done, with the advantage that it was easily adjusted to any desired value.

In Fig. 2, C is the condenser and R the external leak, consisting of an accurately calibrated wire-wound tapped resistance of maximum value 1 megohm. The other reference letters are the same as for Fig. 1. With $V = 2$ volts and a condenser of 2μF, using a first-class pair of telephones of total resistance 120 ohms, and adjusting R to its maximum value, a very faint click was just audible on opening K. Adjusting R to $\frac{1}{2}$ megohm the click was more decided, and with $R = 1/10$ megohm (=100 000 ohms) the click on breaking was unmistakable. With R disconnected no sound whatever was heard on opening K.

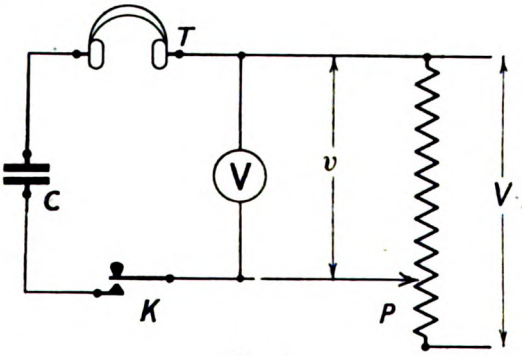

Fig. 3.

Using a condenser of .05μF capacity, the results were exactly similar to the above. The click on closing K was not, however, quite so loud: but as stated above this is of no significance so far as these tests are concerned.

The tests were repeated with a pair of telephones of 2 000 ohms total resistance. Again no sound was heard while R was disconnected, but with a 1 megohm leak a click was considerably more easily distinguishable than with the 120 ohm telephones; in fact, a leak of between 2 and 3 megohms was detected using extra resistances to increase the value of R. Similarly, using 4 000 ohm telephones, a leak of 5 megohms resistance was quite easily detected.

In this manner by using higher voltages smaller leaks up to many megohms resistance might be detected, but these very high resistance leaks should not have any serious effect on the performance of a receiving set.

While the presence of a leak which would be detrimental to the efficient working of a set may be detected in this way, the author does not mean to assert that the magnitude of the leak can be measured with any degree of accuracy unless the current just necessary to produce a click in any given pair of telephones is known. If it is, the most accurate way to proceed (the apparatus being connected as in Fig. 1) is to shunt the telephones with a variable resistance adjusted to such a value that the (second) click becomes so faint as to be just audible, but no more.

Then, from the value of this shunting resistance and the voltage used, it is quite easy to deduce the value of the leak. As, however, this method necessitates the use of a suitably calibrated resistance box, it is hardly possible to the average amateur. On the other hand, if he possesses an accurate voltmeter reading down to fractions of a volt, he may, with the use of an ordinary potentiometer, such as is used for regulating the grid voltage of a valve, make a tolerably accurate measurement of the leak.

Connect up the apparatus as in Fig. 3, where P represents the potentiometer of (say) 300 ohms maximum resistance, and Vm the voltmeter. V, as in Fig. 1, represents the total voltage of the battery used, while v represents the voltage on the other side of the potentiometer. C, T and K are as in Fig. 1. The voltage v is now adjusted until, as before, on opening K only the faintest possible click is audible.

Example: Suppose for a pair of 4 000 ohm telephones the necessary current to produce this click is 0.3 mA (a pair the author recently tested were sensitive to 0.21mA), and suppose vM reads 0.9 volt. Let R be the internal value of a leak through the condenser C, then, by Ohm's law

$$R = \frac{0.9}{0.3 \times 10^{-6}} = 3 \times 10^{-6} \text{ ohms} = 3 \text{ megohms.}$$

Note: Neither the voltage V nor the resistance of the potentiometer need be considered, while the resistance of the telephones is negligible. Also it is necessary to keep the voltmeter Vm in circuit during the whole time of testing.

The following points should be noted in making any of the above tests:—

(1) The condenser to be tested should be completely disconnected from the set, as well as the telephones and battery; otherwise misleading results may be obtained.

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(2) Assume that the condenser is completely short-circuited until you prove otherwise. Therefore, use a low voltage to commence and if necessary insert a resistance of a few hundred ohms value when using low resistance telephones, so that the latter may be protected from excess current.

(3) Always connect the telephones so that the current will enter at the terminal marked positive. A good pair are usually more sensitive when so connected.

(4) Though it is not essential, it is advisable before making a second test to discharge the condenser under test by momentarily short-circuiting its terminals.

(5) A good key or means of making and breaking the circuit is essential if false clicks are not to result.

(6) It is very important that the room be perfectly quiet during the test. Any extraneous noise prevents very faint clicks from being heard.

It is worth remembering that low resistance telephones may be used in conjunction with their telephone transformer when the two together will be equivalent to a pair of high resistance telephones. The primary or high resistance side of the transformer should be connected in the testing circuit exactly where the low resistance telephones previously were, and the latter now connected across the low resistance side of the transformer as when used for reception in the ordinary way. Of course, the transformer must be completely disconnected from the receiving set.

It might be worth while testing one's grid condenser by one of these methods even though no fault is suspected, for it is quite possible that the external grid-leak on the detecting valve may really pass less current than an unsuspected internal leak through the dielectric of a condenser. What is more, it is by no means certain that, if a condenser is faulty, its resistance will remain constant.

Finally it may be remarked that while the smallness of a leak capable of being detected by the telephone is dependent on the sensitiveness of both the observer's hearing and the telephones he is using, yet neither of these factors (over a certain range) will interfere with the accuracy of the measurement of the leak (as distinct from the mere detection of it) provided the observer measures the apparent sensitiveness of his own telephones.

It is not intended that the methods here outlined should be confined to testing condensers: they may equally well be used for measuring any high resistance, and, indeed, with some modifications, low resistances, too.

Addendum.

Note on a method of determining the minimum current to which a telephone receiver is sensitive. The simplest way for an amateur to do this, while still preserving tolerable accuracy in the result, is to connect up as in Fig. 3 above with the exception that some high resistance of *known* value is inserted in the circuit in place of the condenser, which is completely removed. It is suggested that such a resistance might be supplied by a 2 megohm grid-leak of reputable manufacture. Then, as before, the voltage v is adjusted until on either *opening* or *closing* K, only the faintest possible click is heard. Example: Suppose when this condition is obtained, that Vm reads 0.5 volt, then by Ohm's law

$$I = \frac{0.5}{2 \times 10^6} = 0.25 \times 10^{-6} \text{ amps} = 0.25\text{mA}.$$

where I represents the required current.

Apart from the need of this value of minimum current being known for the purpose of testing a condenser, it is of great interest in itself to be able to compare the sensitiveness of two or more telephones.

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The Self-Capacity of Inductance Coils.

By H. J. Barton Chapple, Wh.Sch., B.Sc. (Lond.), A.C.G.I., D.I.C., A.M.I.E.E.

[R382·1

This article describes the results of exhaustive tests made both with commercial and experimental coils

THESE tests were carried out to determine the magnitude of the self-capacity of various inductance coils. The term "self-capacity" is applied to that capacity which, if placed across the terminals of an ideal coil, possessing inductance only and no capacity, would give rise to the same electrical effects as are found in the actual coil. Since this quantity forms one of the main sources of error in the calculation of radio circuits, a knowledge of average values to be expected in practice and a method of deriving them is important.

A condenser in parallel with an inductance coil produces a circuit which at one particular frequency offers a very high impedance to the flow of current through the combination, but the effect of raising the normal effective resistance of the coil is not entirely confined to that frequency to which the coil is tuned by the capacity. In the appendix the magnitude of the increase in resistance, due to self-capacity alone, has been mathematically determined, the approximate result being :—

$$R = R_0/(1 - \omega^2 L_0 C_s)^2$$

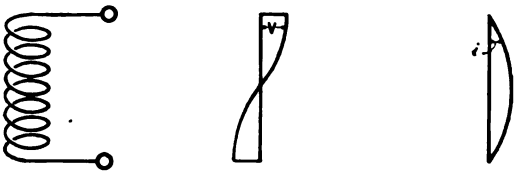

Fig. 2.

where R_0 is the H.F. resistance of the coil, and R the apparent resistance of coil and self-capacity combined.

In terms of wave-lengths, which are perhaps more familiar, the expression can be easily modified to

$$R = R_0/(1 - \lambda_s^2/\lambda^2)^2$$

A curve indicating the ratio R/R_0 against wave-length λ has been plotted for a coil the natural wave-length of which, due to self-inductance and self-capacity, is 200 metres, and is shown in Fig. 1, and even at 2 000 metres a 2 per cent. increase in high frequency resistance is experienced. From this standpoint along, then, the self-capacity of a coil is important.

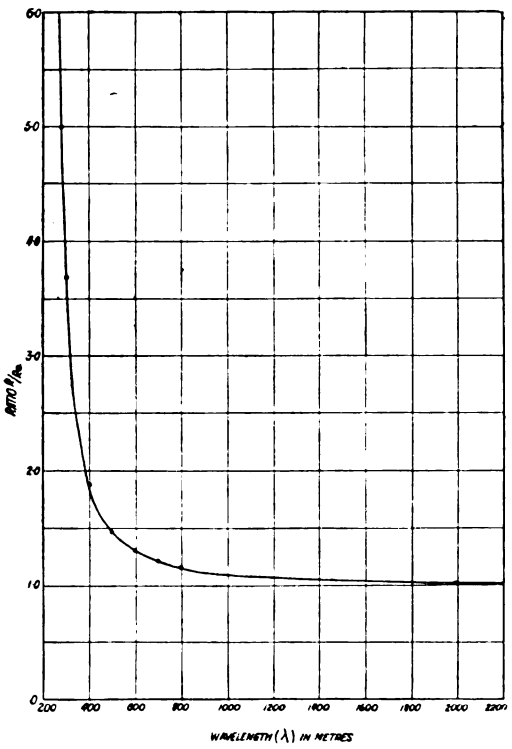

Fig. 1.

Of course it should be borne in mind that this increased resistance only takes effect when the coil is untuned, and is in a circuit being supplied from some other source of E.M.F. When an E.M.F. is introduced into the coil itself by coupling, the effect of the self-capacity is to add to the other capacities in the circuit which comes across the coil. Again, if the coil is tuned by an external added capacity, the whole becomes a rejector circuit, and the increased resistance calculation must now take account of the complete capacity.

In a paper before the Physical Society (Vol. 25, 1912), Prof. Howe indicated

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that the main source of error in the calculation of the frequency of an inductance coil shunted by a condenser was the capacity between neighbouring portions of the coil. Even when the variable condenser is removed, the coil itself has a definite natural frequency, the ends acting as the plates of a condenser and the central portion as an inductance, the two functions, however, being distributed over the whole coil and gradually merging into one another. The potential and current distributions were given as Fig. 2 for the coil alone. Fig. 3 gives the modification introduced by an added capacity.

Further detailed information was given by Prof. Howe in the *I.E.E. Journal*, Vol. 60, page 67, where "The Effective Self-Capacity, Inductance, and Resistance of Coils" was discussed. It was shown that although it is necessary, for practical purposes, to represent the self-capacity by a condenser connected

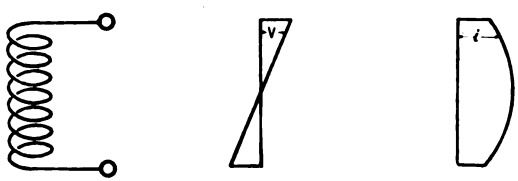

Fig. 3.

across the extremities of the coil, it would appear more reasonable from physical considerations to represent it by a condenser connected across two intermediate points along the coil; between the centres of gravity, as it were, of the positive and negative charges on the coil. Regarding the coil as an auto-transformer, however, this condenser across these imaginary tappings could be replaced by an equivalent condenser of smaller capacity across the extremities of the coil.

In order to test the magnitude of the self-capacity a series of experiments were conducted on the following lines :—

Let C_s = Self Capacity of Coil in μF.
Let L = Inductance of coil in μH.
Let C = Added variable capacity.

Then from the familiar wave-length equation we have

$$\lambda = 1\,885\sqrt{L(C+C_s)}$$
$$\therefore\ \lambda^2 = 1\,885^2 LC + 1\,885^2 LC_s$$
$$i.e.,\ \lambda^2 = k_1 C + k_2,$$

where k_1 and k_2 are constants.

Thus, if the true wave-length of a coil set oscillating in conjunction with a shunted variable condenser is determined, and a graph plotted with λ^2 as ordinates and capacity C as abscissa, a straight line AB will pass through the points as indicated in

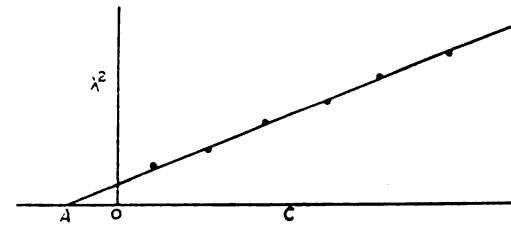

Fig. 4.

Fig. 4. When λ^2 is zero,

$$0 = 1\,885^2 LC + 1\,885^2 LC_s$$
$$i.e.,\ C = -C_s,$$

or the intercept AO gives the value of the coils' self-capacity C_s.

This method is strictly only an approximate one, since it depends for accuracy on obtaining the best straight line among the plotted points. For accurate purposes recourse has to be made to the method of "least squares" as pointed out in the excellent article by P. K. Turner in the March issue of E.W. & W.E., but provided the necessary care and precaution is taken in determining the wave-lengths, and well calibrated apparatus is used, it will be found that the plotted points lie very well on a straight line.

The apparatus employed was a Sullivan Standard Heterodyne Wavemeter (150-20 000 metres range) as a source of high frequency oscillations, and the coil of which the self-capacity was to be determined was shunted by a variable air condenser of high

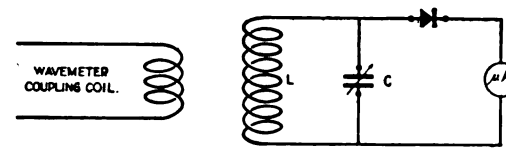

Fig. 5.

grade. With the coupling coil of the wavemeter loosely coupled to this circuit resonance was indicated by varying the wave-length and observing maximum deflection in a unipivot micro-ammeter shunted with a crystal across the given coil, as shown in Fig. 5.*

At resonance the above conditions hold, so a series of values of λ and C was tabulated,

* Strictly, a correction should be made for the self-capacity of this.

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and a graph drawn between λ^2 and C. The ultimate results for a series of coils is shown in the table, due allowance being made for stray capacities.

Description of Coil.	Self Ind. in μH.	Self Cap. in $\mu\mu$F.
B Gambrell	223·5	6
75 Airmax	280·2	25
S5 Burndept	360·1	6
75 Igranic..	323·5	35
H.D.B. slab coil (1½" dia.)	981·0	7
H.D.B. slab coil (1½" dia.)	295·1	22
25 turns of "Mars" wire on red fibre basket former	31·2	17
25 turns of 22's D.C.C. wire on red fibre basket former	33·5	20
Wax impregnated basket coils, 3 cm. inner dia. :—		
(1) 2.4 cm. winding depth	326·3	18
(2) 2.15 cm. winding depth	227·8	16
(3) 1.5 cm. winding depth	105·5	10
(4) 1.25 cm. winding depth	63·0	4
Single layer coils wound with 20's D.C.C. wire :—		
266 turns 20.0 cm. dia.	73 90·0	0
254 turns 18.8 cm. dia.	61 50·0	0
126 turns 15.2 cm. dia.	16 20·0	0
123 turns 13.8 cm. dia.	14 35·0	0
Multilayer coils wound with 24's S.C. wire :—		
2300 turns 3.3" dia. × 1.2"	575 000·0	220
850 turns 1.3" dia. × 0.9"	66 000·0	170
Multilayer coil wound with 36's S.C. wire :—		
3810 turns 6.8" dia. × 1.2"	3080000·0	725

The selection embraces a number of popular loading coils used for broadcast reception, where efforts have been made to reduce the self-capacity to a minimum by recourse to patent winding methods, which will also permit the necessary conditions of compactness and rigidity. These include the familiar banking, sectionalising, interspacing, basket or pancake, honeycomb, duolateral, etc.

From an observation of the results it is clear that the coils with least self-capacity are large, single-layer ones, which, of course, would have been expected. To test the effect of multi-layers a wooden former with winding diameter 1½ inches and winding length 3 inches was wound with 20 gauge D.C.C. wire, so that successive measurements could be made for each layer of 58 turns up to eight layers. The results are appended.

No. of layers	1	2	3	4	5	6	7	8
Self capacity in $\mu\mu$F's..	40	350	178	140	130	125	115	106

The addition of a second layer to the first increases the self-capacity considerably—a result always found in practice; but the other layers tend to counteract this effect somewhat. If the self-capacity is regarded as being entirely due to inter-turn condensers in series and parallel, the reason for this may be simply explained.

For a single layer the capacities between turns are added in series and hence the result is to reduce the resultant capacity. With two layers, however, since the winding is brought back on itself, the total capacity between the terminals T_1 and T_2 must at least exceed the capacity between first and last turn, see Fig. 6, which shows a few turns. Adding another layer, however, brings T_1 across to the other side again and the series effect reduces the capacity once more. Fig. 7.

For the few turns illustrated it can easily be proved mathematically that :—

First Layer Capacity $= C/2$,
Second ,, ,, $= 15C/11$, and
Third ,, ,, $= 2C/3$,

where C is capacity between individual turns.

This can be continued, but, of course, in actual practice the problem becomes far more complicated, due to terminal capacities, capacity to earth, irregular winding, etc. However, the improvement resulting from an addition of further layers beyond the second is worth bearing in mind.

J. H. Morecroft, in his book on the *Principles of Radio Communication*, deals with the problem of the internal capacity of coils, and gives methods for calculating it. He indicates that a multilayer coil constructed with an air space between each layer may have a comparatively small self-capacity, and in a short analysis shows that this capacity decreases with increase of layers to the extent that, if C is capacity between two

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adjacent layers, the internal capacity of a coil with N layers is C/N.

Repeating the same experiment with a larger coil—winding diameter $4\frac{3}{4}$ inches and winding length 6 inches—the same considerable increase of self-capacity for two layers was noted. The prime object in this case, however, was to prove that wire of inferior

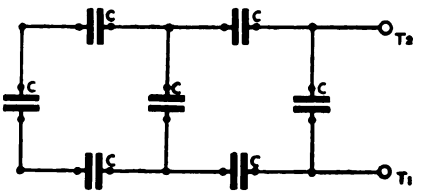

Fig. 6.

insulation gives serious self-capacities; 20 gauge D.C.C. was employed, but the insulation was badly charred in places although the wire was never bare. The values for four successive layers are :—

No. of layers	1	2	3	4
Self capacity in $\mu\mu$Fs. ..	40	710	625	784

The number of turns per layer was 112, and the benefit of added layers above the second was negatived after the third owing to the insulation being very poor. The large self-capacities would make coils of this nature (*i.e.*, solenoidal multi-layer, closely wound) practically useless for short wave work, and the importance of taking extreme care to produce coils of low self-capacity cannot be over-emphasised, in addition to employing wire of best quality insulation.

The above experiments were carried out in the High Frequency Laboratory, Bradford Technical College, and the author wishes to thank Mr. G. N. Oddy for assistance in obtaining a number of the results.

APPENDIX.

Treating the self-capacity as a condenser shunted across the whole inductance, as mentioned previously, we have from the formula for parallel circuits

$$\frac{1}{(R+j\omega L)} = \frac{j\omega C_s + 1}{(R_0 + j\omega L_0)}$$

where

C_s = Coil's self-capacity in farads;
L_0 = Inductance of coil (in henries) with no self-capacity;
R_0 = High frequency resistance of coil with no self-capacity;
R = Effective resistance presented by coil;
L = Effective inductance presented by coil.

$$\therefore\ R + j\omega L = \frac{(R_0 + j\omega L_0)}{(1 - \omega^2 L_0 C_s + j\omega C_s R_0)}$$

Rationalising the expression on the right and simplifying we now have

$$R + j\omega L = \frac{\{R_0 + j\omega(L_0 - C_s R_0^2 - \omega^2 L_0^2 C_s)\}}{\{(1 - \omega^2 L_0 C_s)^2 + \omega^2 C_s^2 R_0^2\}}$$

Equating real quantities

$$R = \frac{R_0}{\{(1 - \omega^2 L_0 C_s)^2 + \omega^2 C_s^2 R_0^2\}}$$

$$= \frac{R_0}{(1 - \omega^2 L_0 C_s)^2}$$

if the quantity $\omega^2 C_s^2 R_0^2$ is neglected in comparison with $(1 - \omega^2 L_0 C_s)^2$.

From the above it is seen that the effect of the self-capacity is to increase the resistance of the coil, the magnitude of the increase depending upon the frequency at which the coil is used.

Now equating imaginary quantities

$$L = \frac{(L_0 - \omega^2 L_0^2 C_s - C_s R_0^2)}{\{(1 - \omega^2 L_0 C_s)^2 + \omega^2 C_s^2 R_0^2\}}$$

$$= \frac{L_0(1 - \omega^2 L_0 C_s)}{(1 - \omega^2 L_0 C_s)^2}$$

If, in addition to neglecting the same expression as before in the denominator, the quantity $C_s R_0^2$ is omitted when compared to $\omega^2 L_0 C_s$, then

$$L = \frac{L_0}{(1 - \omega^2 L_0 C_s)}$$

Thus the inductance of the coil is also increased, but not to the same extent as the resistance; and since the inductance of a coil at high frequencies is

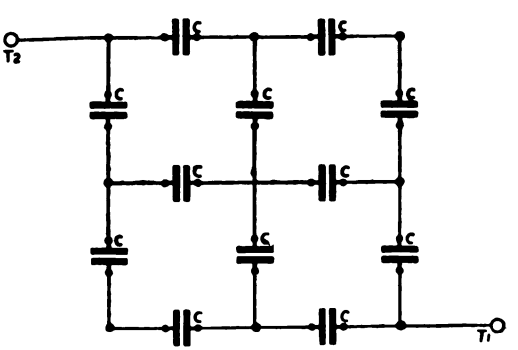

Fig. 7.

less than that measured at low frequencies, it is possible by careful design to balance this decrease against the afore-mentioned increase so that the coil's inductance will not seriously alter at different wave-lengths and affect design calculations.

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Long-Distance Work.

By Hugh N. Ryan (5BV). [R 545·009·2

As was to be expected, work on the waves around 90 metres has now entirely ceased, except for a small amount of local work and work between stations in various European countries. Contact with America on this wave apparently lasted about as long this year as it did last year on 115 metres.

Work on 45 metres, however, is going extremely well. There is apparently little or no diminution in signal strength on this wave as the summer proceeds. Even though only a few stations are in regular operation, compared with those working in the winter months, steady and almost nightly contact with America is being maintained.

Australians and New Zealanders can be heard well on a good night, though what constitutes a good night is yet somewhat doubtful. They are, at any rate, quite frequent. In the early months of our original American work, on 115 metres, many amateurs became quite expert in predicting, early in the winter evenings, whether the coming night would be a good one. 2KF, I remember, was a very prolific (and occasionally accurate) prophet in this connection. Though conditions do vary in modern 45-metre work, it is not possible, I think, to foretell a good or a bad night. The only method is to try it and see. One stands a very good chance of picking a good one. In any case, goodness or badness only means the presence or absence of signals from the Antipodes. The Americans are always there.

Last month I said that, in my opinion, the ideal DX wave-length would turn out to be somewhere around 40 metres. Looking through some back numbers of E.W. & W.E. I find that I made a similar prophecy in December, 1923—putting the ideal wave at 150 metres—"as soon as sufficient amateur receivers could receive such short waves." It is interesting to note that on each occasion I received a number of letters agreeing with me, and a few disagreeing. In the first case those who disagreed said 150 metres was much too low for useful work. This time the critics say 40 metres is too high. I hope they are right, as there is much more room for all of us the lower we go; but I hold to my prophecy.

Stations in the London district have been particularly active during the past month, considering the time of the year. 5LF, I think, has done the best all-round work. Every morning that he comes on he works Americans in large numbers, on his normal power, but the more interesting part of his work has been conducted on a low-power set. This set has a maximum power of two watts and uses a small vertical aerial (on 45 metres). Though he has not worked America with it (yet !), he has obtained some very fine results within Europe, the best report being from Danish 7EC, who reports the signals R7.

2DX has worked Brazil 1AB using only 66 watts (on 45 metres). He has also been heard in India when working on an indoor aerial, signals being reported R7. A report just received from Australia shows 2DX to have been heard in New South Wales, when working on low power to G6TD (Old North Wales !).

The most interesting reception report comes from 6HY, who heard New Zealand 1AR in April, transmitting a concert. He has just received confirmation of this, and sends me an interesting cutting from a New Zealand newspaper, dealing with this feat. 1AR was only using 35 watts input, and 6HY only using two valves.

I was mistaken last month in saying that 5TZ was the only British station who had yet worked Iceland BG1, as I hear that 6DO also worked him in May.

5CV, who was often heard two years ago working from Walton-on-Thames, is now soon starting again, this time in London. 2LZ has been extremely active recently, having worked Brazil 1AB, Argentine CB8, three New Zealanders and two Australians.

Mr. W. K. Islip (a member of the Cambridge Society's experimental section) recently heard Z2XA, who, I think, has not previously been reported in this country. Italian 1NO heard 2XA at the same time and called him, but without success.

Now that a number of British stations have been heard in South Africa, one is glad to note that a South African station has been heard in England. 2KK heard South African A4Z on 7th July. A4Z is now

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working on 48 metres, and it is to be hoped that other British stations will hear him, and soon communicate with him. The South African intermediate letter is "o."

6JV (Norwich) has spent the month comparing experimentally the results of fundamental and harmonic working of the aerial, on 45 metres, and finds that in his case harmonic working gives better results on the same power. The work of this station is noteworthy for the way in which the owner settles down to the investigation of a definite question, and keeps steadily to it. He thus collects a great deal of useful data, though perhaps does not put up any startling DX records. It is, I think, a pity that so many amateurs, undoubtedly competent men and possessing good apparatus, spend so much time in record-hunting, instead of performing more systematic experiments.

2CC has blown the valve on his 45-metre transmitter, and for the time being is working only on a low-power 23-metre set. With this he worked 26 Americans during June alone.

5KO, once of Bristol, who was so well-known to all of us in the old days, is at last coming back "on the air," this time at Newcastle. This is very good news. 2MG is not working at present, but 2TF is keeping the 23-metre wave alive in Scotland, while 2VX does the same for the 96-metre wave.

2VX has worked a number of European countries in daylight with nine watts, and, in the nearly-darkness which passes for night in summer in Aberdeen, has worked 8ALG (North Africa) and BSM (Palestine).

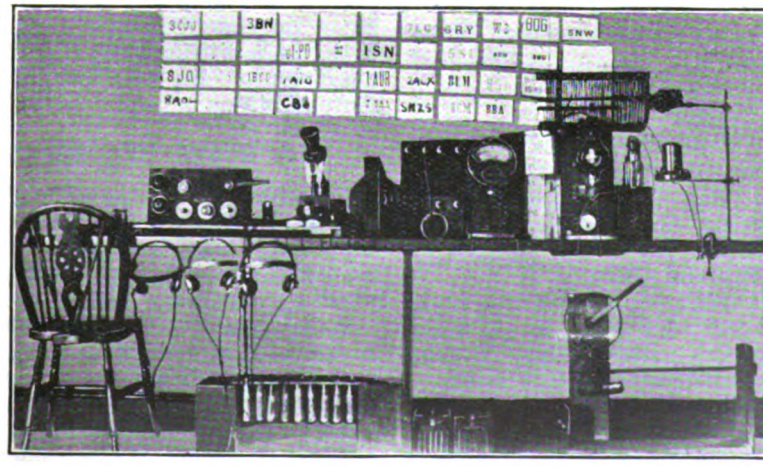
Mr. Neill, of Belfast, is now working again, and has at last a transmitting licence, his call being 5NJ. He now uses a superhet for all receiving work and has received 2NM and 2KF on 45-metre telephony in the early afternoon.

Last month I mentioned that 6YM's voyage had been somewhat disappointing from our end. I perhaps did not make it clear that this only applied from our end. The voyage was not made for the purpose of working a lot of stations, but for making observations, and in this it accomplished its object most successfully, though certainly more British stations would have liked to work the ship-station as a matter of interest.

One of the northern amateurs, 2JO, has gone to Borneo, and will be there by the time this appears. He has taken some of his station with him, and hopes to get in touch with us, probably on 45 metres. I do not yet know what call-sign he will use there.

By the way, when I mention a fairly new station in these columns, it often happens that other stations, having reports for them, and not knowing their addresses, send the cards to me, under cover, for forwarding. While I am glad enough to do this, I think one might expect the cards to be stamped—which they seldom are!

Next month's reports by 10th August, please.



A photograph of Amateur Station 6TM This is described in detail on page 701, et seq.

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For the Esperantists.

A GLIMPSE AT ESPERANTO.

The Alphabet.

A B C Ĉ D E F G Ĝ H Ĥ I J Ĵ K L M N O P R S Ŝ T U Ŭ V Z.

No Q, W, X, or Y.

Pronunciation.

The Vowels: **A** (bah) **E** (there) **I** (pier) **O** (pore) **U** (poor)

The **Consonants** sound as in English, except **C** like **ts** in **bits**, *e.g.*, **caro** like *tsaro*; **acido** like ah-tsee'-doh. **Ĉ** like **ch** in **church**. **G** like **g** in **go**. **Ĝ** like **g** in **gem**. **-J** like **y** in **yes**, *e.g.*, **jaro** like *yaro*; **bojo** like *boyo*. **Ĵ** like **z** in **azure**. **S** like **s** in **so**. **Ŝ** like **sh** in **show**. **H** (guttural, very seldom used) like **ch** in **loch**.

AJ, OJ, as in **my boy**. **EJ,** as in **obey**. **UJ,** as in **hallelujah**. **Ŭ** is the Esperanto **W,** as in **well, how**; **AŬ** as **ow** in **cow**. **EŬ,** as in **they—were**.

Accent always on the second last syllable. Phonetic spelling. **-O** is the ending of the **NOUN**. **ADJECTIVES** end in **-A**.

Nouns and adjectives form the **PLURAL** by adding **-J**.

The simple **VERB** endings :—

Infinitive.	Present.	Past.	Future.	Conditional.	Imperative.
I	**AS**	**IS**	**OS**	**US**	**U**

N marks the **ACCUSATIVE** (direct object). **ADVERBS** end in **E**. **NO IRREGULARITIES.** **NO EXCEPTIONS.**

Distordado. [R800

Serio de artikoloj verkitaj de teknika spertulo por montri la kaŭzon de la nebona tonkvalito de nuntempaj aparatoj, kaj kiumaniere oni povas ĝin eviti.

PARTO I.

LA ĈEFAJ PRINCIPOJ.

La unua celo estas korekti tre ĝeneralan kredon. Verŝajne estas la kutimo ekskuzi malbonan kvaliton, kulpigante la laŭtparolilon. La verkanto opinias, ke ĉe granda plimulto da okazoj, la kulpo estas tute ne de la laŭta parolilo. Jen, liaopinie, la ordo de la ĉefaj kaŭzoj de distordo :—

1. Netaŭgaj valvoj kaj malbona valvalĝustigo ;
2. Malbona intervalva kupleco ;
3. Malbona laŭtparolilo ;
4. Netaŭga aranĝo por detektado.

Konforme al tiu vidpunkto, ni unue pritraktu la valvon. Tiu ĉi artikolo faros simplan studon pri funkciigo de valvo por malaltfrekvenca amplifado, kaj finiĝos per resumo de praktikaj instrukcioj.

Ni unue akcentu, pri laŭtparolila funkciado, kiun ni nun konsideras, ke oni devas ne forgesi, ke ni nun pritraktas la amplifadon de potenco. Se ni sugestus, ke 2LO (Londona Stacio) anstataŭigu la 1-kilovatajn valvojn per "R" (malgrandaj ricevaj) valvoj por la ĉefa senda amplifikatoro, ĉiu kompreneble ridus. Oni prave dirus, ke ili ne povus produkti la bezonitan elmeton. Sed oni verŝajne ne ekkomprenas, ke ĝuste la sama rilatas al funkciigo de laŭta parolilo.

Kiam oni uzas telefonilon, la demando ne okazas, ĉar ĉia komerca valvo havas sufiĉan potencon. Sed laŭta parolilo bezonas kelkmiloble da potenco ol telefonilo, kaj ekzistas multe de ricevaj valvoj (inkluzive la "R"), kiuj *ne* kreas sufiĉe da elmeta potenco por la laŭtparolilo.

Oni devus kompreni, ke ĉiu valvo, je sia taksita filamenta varmeco, havas difinitan limon de elmeta potenco. Sed multe sub ĉi tiu limo ekzistas alia : la limo de elmeto sen distordo ; kaj estas ĝuste tio, kio gravas rilate al nia nuna celo.

LA GUSTA UZO DE VALVO.

Evidente, ĉi tiu konsiderado kondukos nin al rekomendo por la utiligo de altpotencaj valvoj kiam bezonataj, kaj ni devas rimarkigi pri alia ĝenerala eraro. Oni *ne* uzas altpotencan valvon por ricevi pli laŭtajn signalojn ol per ordinara valvo. Efektive, ĝi ofte amplifas malplimulte. Oni uzas ĝin por ricevi *laŭtajn signalojn sen distordo.*

La kialo por tio estas videbla post rigardo al Fig. 1, kiu montras la karakterizan kurvon de tre konata kaj tre bona riceva valvo. Oni rimarkas, ke la anoda kurento varias

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de 0 ĝis preskaŭ 5 miliamperoj laŭ la variado de la krada tensio; la anoda tensio estas 160 voltoj—sed tio estas negrava nunmomente. Nu, kiel oni vidas, la "kurvo"

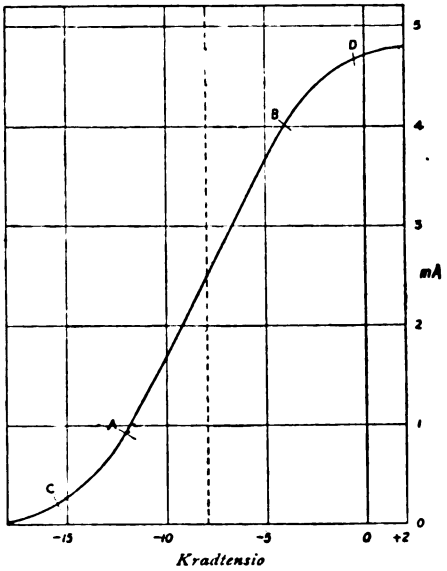

Fig. 1.

estas "rekta," aŭ preskaŭ rekta inter 1 miliampero kaj 4, interrespondante al kradtensioj de —4 kaj —12. Do, se ni aldonos 8 voltojn al la krado, la malaltfrekvenca enmeta tensio povus havi amplitudon de 4 voltoj, dum ĝi ankoraŭ funkcias je la rekta parto de l'kurvo.

La unua regulo pri bona kvalito ĉe amplifikatoro estas, "neniam forlasu la rektan parton"! Oni kutimas paroli pri la tuta voltŝanĝo kaŭzita de la alterna enmeto—la amplifita muziko de la valvo antaŭa—kiel la "svingiĝo." Je la nuna okazo, la valvo povus porti svingiĝon de 8 voltoj.

Sed tio ne estas sufiĉa.

Oni multe eksperimentis lastatempe pri mezuro de la svingiĝo ĉe efektivaj amplifikatoroj, kaj la rezulto estas ke, kiam ordinara laŭtparolilo bonforte funkcias en mezgranda ĉambro, la meza svingiĝo ĉe la krado de la lasta valvo estas ĉirkaŭ 15 voltoj. Koncerne la aluditan valvon, se ni fiksus la kradtension je 8 voltoj (la plej taŭga pozicio), la signalo variigus la kradtension de —½ ĝis —15½, aŭ de C ĝis D sur la kurvo.

Tio signifas, ke ĉiu muzika tono ricevus aldonitan tonon proksimume unu oktavo-kaj-duono pli altan, kaj emisius la bone konatan "gramofoneman" tonon. Tute ne helpus al ni "ludado" je kradaj kaj anodaj voltoj, ĉar la kurvo ne permesus svingiĝon de 15 voltoj. La sola efiko de plia alta tensio estus kvazaŭ la kurvo moviĝis maldekstren; ĝi ne plilongigus la rektan parton.

LA UNUA PUNKTO.

Estas nur unu metodo tion fari—plivarmigi la filamenton. Sed la valvo pri kio ni traktas estas taksita je "3.6 ĝis 4 voltoj," kaj la kurvo estis farita je 4.2, do ni jam iomete troŝarĝas ĝin, kaj la vivo de la valvo estus serioze mallongigita se ni plue ŝarĝus ĝin.

La vera kuraco estus uzi valvon desegnitan por produkti la bezonitan potencon. Kiel tio efektivigas nian celon estas videbla per Fig. 2, kiu montras tri kurvojn por malsamaj filamentaj varmecoj de bone konata altpotenca valvo de la tipo 435 (4 voltoj, 0.35 amperoj). Ĉiuokaze la kurvo reprezentas valoron de altatensiaj voltoj, kiu portas la supran finon de la kurvo. Ni vidas ke, kun 3.2 voltoj ĉe l'filamento, la "svingiĝo" povus atingi 10 voltojn (A ĝis B); je 3.6 voltoj, la svingiĝo estas 22 (C ĝis D); kaj je 4 voltoj, 36-volta svingiĝo estas permesebla—sufiĉa por malgranda halo.

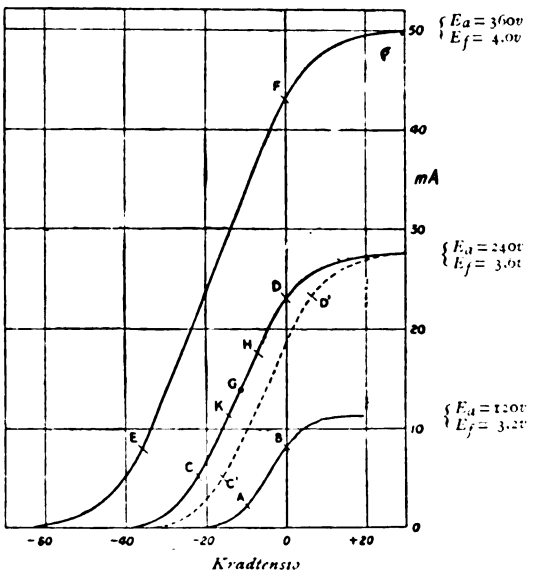

Fig. 2.

Jen, do, nia unua punkto: *Por la lasta valvo uzu specon, kiu permesas 15-voltan svingĝon sen troŝarĝo.*

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Jen kelkaj britaj valvoj gradigitaj laŭpotence :—

L.S.5. Tiu ĉi estas altoptenca valvo Marconi'a, iom altpreza. Bonega por eksterdoma aŭ koncerta funkcio. Efektive pli potence ol necese por ĉambro. 4v, .8a.

P.V.5.D.E. Jen Ediswan'a valvo de tipo 625 (6v, .25a), aparte citita pro tio, ke ĝi verŝajne havas pligrandan elmeton ol multaj samtipaj.

Tipo 625. Preskaŭ ĉiu granda firmo fabrikas tiun specon. Bonege taŭgas por endoma funkcio.

Tipo 435. (4v, .35a). Simila valvo kiel la tipo 625, sed ĝi portos pli altan filamentan kurenton je plimalalta tensio ; ĉu uzi ĉitian aŭ la 625-specan dependas nur, ĉu oni preferas 4- aŭ 6-voltan baterion.

Tipoj 606 kaj 312. (6v, .06a kaj 3v, .12a.) De potenco malplialta, sed sufiĉa por endoma funkcio, kvankam oni devas uzi ilin ĝis preskaŭ maksimuma taksita tensio. La unua portas treege malaltan filamentan kurenton, dum la dua estas oportuna, ĉar ĝi utiligas la saman filamentan baterion kiel la " .06 "—aj valvoj.

Tipo 240. (2v, .40a.) Tre simila al la tipo 235 (2v, .35a), de valvo por ĝenerala uzado ("duone malhela"). Efektive nesufiĉe forta por granda ĉambro, sed bonega por malgranda ĉambro.

Ĉiun supre aluditan valvon (escepte la unuaj du) fabrikas, sub diversaj nomoj, bonekonataj valvfirmoj.

Tiom pri elekto de la lasta valvo.

LA ANTAŬAJ ŜTUPOJ.

Koncerne valvojn por la antaŭaj ŝtupoj de amplifado, ni povas facile kalkuli la svingiĝon traktotan de ili. Se, ekzemple, ni uzas transformatoran kuplon por la lasta ŝtupo, kaj la transformatora proporcio estas 1—4, kaj ni intencas uzi por la antaŭa ŝtupo valvon kun pligrandiga povo de 8, tial la "pligrandiĝo" de krado al krado trans la ŝtupo estas 8 (por la valvo) × 4 (por la transformatoro), aŭ 32 ; kaj ĉar la lasta valvo havas 15, tiu antaŭ ĝi havos svingiĝon duonvoltan ĉe sia krado.

Ekrigardo al kelkaj karakterizaj kurvoj montras, ke ia ordinara valvo kapablas sufiĉan elmeton ; do ni trovas ke, por "hejma" funkcio, sole ĉe la lasta ŝtupo estas bezonata altpotenca valvo. Eĉ se ŝoka aŭ rezistanca kuplo estas uzata, la svingiĝo ĉe l'valvo antaŭa ne superos 4 ĝis 6 voltojn, ankoraŭ portebla de ia ordinara valvo.

Kontraŭe, por celoj pligravaj ol hejma funkciado, estas necesaj valvoj de multe pli alta potenco ol tio, kion oni ĝenerale kredas. Ekzemple, dum la demonstracioj ĉe la du britaj ekspozicioj pasintan aŭtunon, la lasta ŝtupo havis 8 valvojn (Tipo L.S.5A), paralele aranĝitaj (la L.S.5A estas simila al la L.S.5, sed speciale por la malalta pligrandigapovo de 2) kun 300-volta kradtensio, 700-volta altatensio, kaj konstanta anoda kurento de preskaŭ triono da ampero. Tamen ĉi tiu aspekto estas afero de specialistoj, kaj ni ne intencas trakti ĝin.

Good Work on Standardisation

IT will be remembered that some months ago, at the joint request of the Ebonite Manufacturers' Association and of the Radio Society of Great Britain, a committee was set up by the British Engineering Standards Association to determine a British Standard for Ebonite for wireless purposes. The work of this Committee is well in hand, but a further move in the matter of standardisation of wireless parts has now been made.

A few weeks ago the R.S.G.B. sent a request to the British Engineering Standards Association to call a meeting of all concerned to consider the advisability of forming a Committee for the standardisation of wireless apparatus and components. On the 25th May there was held at the B.E.S.A, a conference at which were represented the R.S.G.B., the National Association of Radio Manufacturers and Traders (N.A.R.M.A.T.), other manufacturers, the Valve Manufacturers' Association, the Institution of Electrical Engineers (Wireless Section), the B.B.C., the Wireless Retailers' Association, the Wireless Board, the G.P.O., and the Technical Press.

This Conference passed unanimously a resolution to the effect that the setting up of such a Committee is highly desirable.

Among the matters to be considered the following were mentioned :

1. Physical dimensions ;
2. Maximum error from rated electrical values ;
3. Suitability of the electrical and mechanical qualities of the materials to be used ;
4. Uniformity of nomenclature, particularly as regards valves and inductance coils.

The purchasing amateur is warned not to expect to see definite standards within a few weeks, or even months, but the first step has been made.

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Letters of interest to experimenters are always welcome. In publishing such communications the Editors do not necessarily endorse any technical or general statements which they may contain.

A New Organisation.

The Editor, E.W. & W.E.

SIR,—If one reviews the wireless societies which exist at the moment, and at the same time peruses the Wireless and Technical Press, one is forced to the conclusion that a really technical society is wanted in Britain—a society which would correspond to the Institute of Radio Engineers of America.

This subject has been talked over between a number of professional men and advanced amateurs, and it has been decided to go ahead with the forming and registering of such a body. A sufficient number of keen wireless men have agreed to find the necessary capital for registering, and to see the matter through; but to ensure lasting success there must be a large membership so that offices can be secured and good proceedings issued at not infrequent intervals.

It is intended that the Society shall be called the British Institute of Radio Engineers. The rules and regulations would, as far as possible, be taken from the constitution of the Institution of Electrical Engineers, or a similar body.

The classes of membership proposed are: Fellows, Members, Associate Members, Graduates and Students. Entrance would be by examination after proposal and seconding by not less than four corporate Members or Associate Members.

The body would be a non-political one and would deal only with the technical side of wireless. It would not attempt to deal with the non-technical side of broadcasting. An effort would be made to issue proceedings of value at monthly intervals.

It should be clearly understood that a professional standing would be adopted in all matters, and that the headquarters would eventually be situated in London.

The Society is actually in the proceess of being registered, so will all those interested or willing to co-operate please send in their names either to Mr. Y. W. P. Evans, M.I.R.E., 66, Oxford Road, Manchester, or to the writer, at an early date, and at the same time indicate the class of membership for which they would apply.

JAMES NELSON, M.I.E.E.

7, High Street,
Prescot.

The Editor, E.W. & W.E.

SIR,—I understand that Mr. James Nelson has sent you a letter outlining the proposed Institute for Radio Engineers, and I shall be glad if you will publish in your next issue this short report of the result of the discussion which has taken place within the last fortnight regarding this matter in the *Electrician* and *Electrical Review*.

We have had over 60 applications for membership, several of which are made by persons holding positions exclusively wireless, and who are not really in a position to enter the Institute of Electrical Engineers, owing to the fact that the rules of this Institute place electrical knowledge far above wireless knowledge, and we have received letters from members of this Institute stating that the Wireless Section is very well catered for in London, but that very little has been done in this respect in the provinces.

We have also received letters which are definitely against the formation of another Institution and stating that the radio engineer is fully provided for by the Wireless Section of the I.E.E. The curious part about these communications is that they are from electrical engineers, and it seems that there will be some difficulty in endeavouring to impress upon the Electrical Engineering Branch that radio engineering is an entirely separate profession, in which electrical science forms only a part of the knowledge required by a fully qualified radio engineer.

It is earnestly hoped that your readers will send their views on this subject in order that we may gauge the feeling of the radio engineer in regard to a separate Institute in this country.

Yours faithfully,

Y. W. P. EVANS,
Hon. Secretary Temp.,
Proposed British I.R.E.

66, Oxford Road,
Manchester.

Short Wave Oscillations Generated by Incandescent Lamps.

The Editor, E.W. & W.E.

SIR,—In experimenting at night time with the 5-metre receiver described in the issue of this journal for December, 1924, I have been troubled with a peculiar form of 50 cycle interference due in some way to the house lighting supply which is A.C. of this periodicity. The peculiar thing, which I noticed from the first, was that this 50 cycle hum tuned in to fairly well-defined maxima at certain settings of the 5-metre tuner and was particularly

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loud when the set was just oscillating. The sound was rather like that produced by a valve transmitter using raw A.C. supply on the plate except that its tuning spread over a rather broader band. For some time I was under the impression that the effect was only observable when the receiver was actually oscillating and that it was due to some obscure form of modulation by the house wiring carrying A.C. A few days ago, however, I went into the matter more carefully and found it possible to tune in the hum on a completely non-oscillating receiver. Moreover, on switching off the incandescent lamp in my room the interference ceased. The next step was to light the lamp and couple it closely to the receiver; on doing this the interference could be tuned in as a loud roar without the use of reaction. This demonstrated almost conclusively that the lamp was generating oscillations. These oscillations can be stopped completely by holding a small steel magnet near the lamp. A piece of brass or other non-magnetic metal similarly held has no effect. The oscillations are therefore very susceptible to feeble magnetic fields. The type of lamp in which I noticed these oscillations was the ordinary metal filament, hard vacuum lamp taking 60 watts at 105 volts. Gas-filled lamps produce no oscillations. Two similar ordinary lamps produced oscillations of about the same frequency although there was a slight difference. The insertion of chokes in the leads to the lamp or the shunting of the lamp by a large condenser seems to have little effect on the oscillations produced. The effect seems, therefore, to be localised within the lamp itself. The oscillations are stopped if the hand is placed round the lamp. Sometimes a lamp requires an impulse to start it oscillating. If the voltage applied to the lamp is increased the frequency of the oscillations is also considerably increased. This, of course, brightens the lamp a good deal and the intensity of the oscillations is increased. Since the frequency is a function of the voltage it will vary over the A.C. cycle with a consequent broadening of the wave-band, which explains the absence of any heterodyne note. The next obvious thing to do was to try a lamp working on D.C. mains. Some brief tests with a D.C. lamp showed that it was also capable of producing oscillations, but this line of investigation has not been properly followed up yet.

How these oscillations are produced in the lamp is not at all clear. I have taken care to make sure that they are not due to sparking at any loose contact in the lamp-holder. Their intensity is quite feeble but is sufficient to cause serious interference with a 5-metre valve receiver in the same house. The hum due to the oscillations can be received on a crystal detector and phones without amplification if the lamp is brought within a few inches of the tuner. The production of ultra-short wave-length oscillations under peculiar conditions in thermionic valves has been noticed by Barkhausen and Kurz in Germany and by Gill in this country and perhaps the lamp effect is an allied phenomenon. If the 105-volt lamp with its 18 inches or so of filament gives out waves of the order of 5 metres, is it not possible that a smaller lamp, say the 12-volt size, might form a source of much shorter waves?

E. H. ROBINSON (2VW).

London, N.W.3.

Experimental Work in Russia.

The Editor, E.W. & W.E.

SIR,—In the May, 1925, issue of your valuable journal on page 511 is published a short article on wireless in Russia, and the work of the wireless laboratory at Nijni-Novgorod.

It is very regrettable to find that so many difficulties are placed in the way of obtaining a knowledge of the state of affairs in this country.

All our work (from 1918) has been recorded in our wireless journal (*TiTbp*), which is published by the laboratory, and is sent to many foreign wireless engineers and editors. Unfortunately, this journal is, of course, printed in the Russian language.

One of the most famous discoveries made in our laboratory is that of the oscillating crystal, by M. Lossew (Jun.), which has been fully described in many wireless journals in Europe during 1924 and 1925. This rectifying-oscillating circuit is very useful to amateurs as a source of amplification without the use of valves.

M. A. Bontsch-Brujewitsch is now Director of the laboratory, and not myself. His 100kW valve is in course of construction, while the 25kW one has been in use since 1923. With the aid of this, Mr. W. W. Tatarinov, also of our laboratory, has developed his scheme for short wave (85-100 metres) transmission with a power of 10kW. With this transmitter a description of the celebrated work of S. A. Popoff was broadcast to the world on 6/7th and 7/8th May, 1925. The message was received by the Geltov Transradio station very loudly and steadily. The transmission was also heard in India (near Calcutta), Chili, Java, Porto Rico, Brazil, Argentina, Africa, and the Belgian Congo.

I also wish to state that the "oil and filings" method of producing very short waves (0.082 mm. to 40 mm.) due to Mme. Glagolewa-Arkadjewa, described in E.W. & W.E., March, 1925, page 343, was first published in our journal *TiTbp* in March, 1924.

Prof. W. K. LEBEDINSKY.

Nichnij-Novgorod.

Stability in H.F. Amplifiers.

The Editor, E.W. & W.E.

SIR,—I am particularly interested in the series of articles on "The Perfect Set," as my hobby, since broadcasting started, has been the attempted elimination of distortion in telephony reception. For some years I have been using a variable stabilising resistance in the oscillatory circuit, and for convenience and effectiveness I know of nothing better. Personally I prefer to connect the resistance in series with the inductance in the oscillatory circuit. If the amplifier is carefully designed it does not need a high resistance here to obtain stability. Even considering the 400 ohms mentioned, the D.C. voltage at the anode would only be reduced by about half a volt. When working on the broadcast wave-lengths and using the condenser near the bottom of the scale a considerably larger damping resistance has to be connected in series with the condenser. The explanation is, I think, that the capacity of the wiring then forms a not inconsiderable part of that in the oscillatory circuit.

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When speaking of "potentiometers of the usual 400 ohm type," I believe you mean those wound on a thin flat former. To many of us the "usual type" is the straight cylindrical form, which is, of course, unsuitable for the purpose.

An easy way of obtaining stability without any special device is by the use of a smaller inductance and more capacity, thus increasing the oscillatory current and so the losses. However, this is an arrangement which I do not like.

H. H. DYER.

22, Leopold Street,
Derby.

DX Records.

The Editor, E.W. & W.E.

SIR,—With reference to a letter from Mr. J H. Ridley (5NN), published in your issue for July, in which the writer claims to be first station to communicate over long distances on wave-lengths of the order of 18-23 metres in any part of the world, I am giving a few details of experiments carried out by stations in Great Britain, Australia and America long before the date given by Mr. Ridley.

February and March, 1925.—Signals received at various times from American Stations 1XAM, 1CMP, 1CCX, IXU, 3APV and 6TS in England on 20 metres.

8th March, 1925.—Successful two-way communication between G5LF and UNKF, Washington, D.C., U.S.A., on 18.3 metres. These experiments were continued for one month with great success each day at 5 p.m. G.M.T.

28th March, 1925.—Successful two-way working between G2KF and U1CMP on 21 metres at 5 p.m. G.M.T.

14th April, 1925.—Successful two-way communication between G2KF and U1CMX on 23 metres at 5.30 p.m. G.M.T.

15th to 18th April, 1925.—Signals from A2CM, Sydney, Australia, copied solid for two hours each morning by G2KF, wave-length 21.5 metres.

19th April, 1925.—Signals from G2KF on 23 metres, logged by A2CM through heavy static.

Whilst *not* wishing to have the fullest possible publicity given to these achievements, nor claiming to be the first experimenter to communicate over long distances on short waves, I shall be glad if you can find an odd space in your correspondence page to publish this letter, which I am sure will be of interest to amateur transmitters and other experimenters.

In conclusion, I would mention that American amateur stations on the Atlantic and Pacific coasts had exchanged signals on 20 metres some time before the dates given above, when they were logged in this country.

J. A. PARTRIDGE (G2KF).

22, Park Road,
Colliers Wood, S.W.19.

Amateur Transmission in Northern Ireland.

The Editor, E.W. & W.E.

SIR,—It is with very great pleasure that I write to inform you that the Government of Northern Ireland has now permitted me to carry out experiments in wireless transmission, and a licence has accordingly been issued to me by the Post Office.

It is proposed to commence transmission experiments from my station about the middle of August, on wave-lengths of 23 and 45 metres, and the help of British experimenters in these tests would be much welcomed. The station's call sign is 5NJ, and the address is "Chesterfield," Whitehead, Co. Antrim, Ireland.

As this station has been appointed Official Observation Station to the T. & R. Section of the R.S.G.B., I should like to state that, as far as possible, I am at all times very pleased to listen for and report to members of this section on wave-lengths of from 18 metres upwards.

I also wish to tender my best thanks to my many friends in England for the valuable help they have given me at various times, and particularly to Mr. E. J. Simmonds (2OD), Mr. G. Marcuse (2NM) and Mr. A. J. Cooper (5TR).

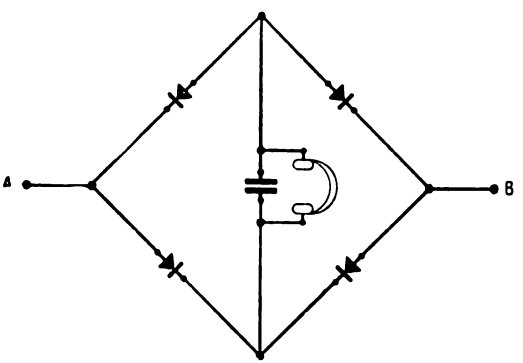
F. R. NEILL.

"Chesterfield,"
Whitehead, Co. Antrim, Ireland.

Full Wave Rectification.

The Editor, E.W. & W.E.

SIR,—With reference to the discussion following the R.S.G.B. lecture on Rectification in which full wave rectification was suggested, the following experimental results may be of interest.



A comparison was made, somewhat roughly, of the signal strength of 5XX at a distance of about 130 miles, first with the ordinary crystal rectifier, and then with the arrangement of four similar detectors shown in the diagram, the input being across A B. The adjustment of the detectors was tested both before and after the combination was used, by means of a suitable switching arrangement, as a check on the results.

Two types of detector were tried, one of high, and one of low, resistance. The former was silicon-copper, and the latter Hertzite-copper.

As far as could be judged, the combination gave results almost identical with those of the single detector. There was certainly no improvement.

W. R. HARPER.

St. John's College,
Cambridge.

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Station News.

The Editor, E.W. & W.E.

SIR,—I beg to inform you that the call sign 5QT has been allotted to me. I expect to commence transmission shortly on wave-lengths of 23 and 45 metres. Detailed reports will be greatly appreciated and all QSL cards will be acknowledged.

A. DAVIDSON.

21, Queen Street,
Worksop, Notts.

The Editor, E.W. & W.E.

SIR.—Please note the following amendment *re* my transmitting station, 5DV; 10 watts C.W. and telephony. I now sign myself,

D. WHITTAKER, B.Sc. (Hons.).

56, Park Road,
St. Annes-on-Sea.

The Editor, E.W. & W.E.

SIR,—The call sign 6SU has been allotted to me, and all reports on my transmissions are welcomed.

ERIC A. PARSONS.

111, Chester Terrace,
Brighton.

The Editor, E.W. & W.E.

SIR,—I should be pleased if you would publish the fact that my call sign 2ABR has been changed to 6VP. Reports of C.W. transmissions on 90 metres will be appreciated and acknowledged.

ALAN SMITH.

48, High Street,
Yiewsley, Middx.

The Editor, E.W. & W.E.

SIR,—The call sign 2OK has been allotted to the C.A.V. firm, Acton, and 2VL to C. A. Vandervell, 87, Holland Park, W.11.

We shall be glad if you will insert these in your next issue.

(For C. A. Vandervell & Co., Ltd.),
C. A. VANDERVELL.

London, W.3.

The Editor, E.W. & W.E.

SIR,—Will you please insert a short notice in your next issue to the effect that the QRA of G2NJ is as given below.

Power 10 watts, C.W. and I.C.W.

N. JOHNSON-FERGUSON.

Luckington Court,
Chippenham, Wilts.

The Editor, E.W. & W.E.

SIR,—I should be favoured if you would make it known through your correspondence columns that in place of my old call-sign, 2AMG, the call-signal 2VR has been allocated to my station.

Transmissions are conducted, generally during week-ends, on wave-lengths of 115-130 metres.

Reports are welcomed and all QSLs answered.

F. W. WILSON.

115, Richmond Road,
Montpelier, Bristol.

The Editor, E.W. & W.E.

SIR,—I should be very grateful if you would publish the following facts: I am now transmitting from two addresses, and would welcome any reports. The wave-lengths in use are 45 metres and 90 metres. Call sign—6BD. Addresses: "Tullagee," Wellington Road, Eastbourne (permanent address); and Wellington College, Berks.

F. M. G. HUTTON.

The Orange,
Wellington College.

Misuse of Call Sign.

The Editor, E.W. & W.E.

SIR,—I have received at various times three reports of telephony transmissions from a station calling 5JX, on broadcast wave-lengths, and in each case from Yorkshire.

As my station (5JX) only works on short wave morse now, any such transmissions as the above are unauthorised, and it is hoped that the offender will cease to use this call.

MARCUS G. SCROGGIE.

19, St. Mildred's Road,
Lee, S.E.12.

Addresses Wanted.

The Editor, E.W. & W.E.

SIR,—As the present addresses of the following members of this Society are unknown, I shall be grateful if you will be good enough to make an announcement in your columns asking them, or anyone who knows their present whereabouts, to communicate with me. I have certain literature and copies of the Society's Journal which I wish to forward to them. I give their last known address in each case:—

F. G. Aylott, Esq., 8, Sumatra Road, Kilburn, N.W.6; L. Birch, Esq., 30, Limesford Road, Waverley Park, S.E.; F. H. Dupre, Esq., 2, Edinburgh Mansions, Howick Place, S.W.; P. V. Dupre, Esq., 101, Dartmouth Road, Brondesbury, N.W.2; J. G. Evans, Esq., "Highbury," Harrop Road, Hale, Cheshire; H. A. S. Gothard, Esq., 8, Longford Terrace, Folkestone; E. Hare, Esq., "Penelve," Leiston, Suffolk; Captain Sir J. K. Mackensie, Bart., F.R.C.S., 19, Upper Richmond Road, S.W.15; G. Mahon, Esq., 11, Haymarket, S.W.1; F. Marshall, Esq., Junr., 2, Park Lane W.1; J. C. Mason, Esq., 16, Cressingham Road, New Brighton, Cheshire; Captain Simon Orde, 16, Pelham Crescent, S.W.7; J. B. Purefoy, Esq., c/o Royal Automobile Club, S.W.1; Rev. Phillip S. Sidney, 4, River Terrace, Sunbury-on-Thames; W. M. Smith, Esq., 3, South Tay Street, Dundee; H. J. Talbot, Esq., 1 South Hill Mansions, South Hill Park, N.W.3.

H. A. ROCK
(for Hon. Secretary),
Radio Society of Great Britain.

53, Victoria Street,
London, S.W.1.

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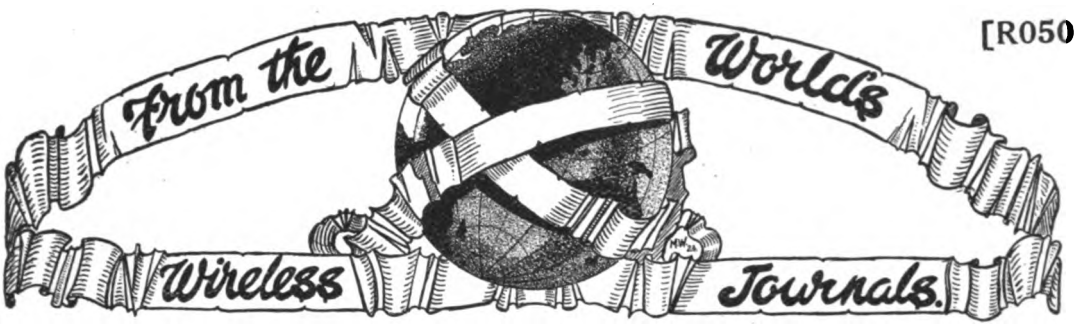

[R050

R100.—GENERAL PRINCIPLES AND THEORY.

R112.—Re-Radiation from Tuned Antenna Systems.—Henry C. Forbes. (*Proc. I.R.E.*, June, 1925.)

The paper considers Dellinger's treatment of the radiation from aerial systems, and applies correction factors thereto for the field-strength near to the aerial. The term "equivalent height" is suggested and is differentiated from effective height. The expressions are then applied to the case of a tuned receiving aerial to determine the distortion produced in the field of a distant transmitter by re-radiation from the receiving aerial. The calculated results are then compared with the field distortion found by the Bureau of Standards near the Washington Monument, and also with measurements made near a typical aerial. The distorted field is found to have practical application as a means of eliminating interference in short distance transmission without a local source of power and in providing a means of measuring the equivalent height of an aerial system.

R113.1.—Fading Measurements.—E. A. Anson. (*Exp. W.*, July, 1925).

Results are given of some quantitative observations on instant broadcasting stations. Observations are also made upon distortion effects.

R113.1.—Some Recent Observations on Periodic Fading and the Night Effect.—Paul D. Tyers (*Exp. W.*, July, 1925).

Results are given of some quantitative observations on distant broadcasting stations. Observations are also made upon distortion effects.

R140.—Computation Charts.—R. S. MacArthur, *Q.S.T.*, June, 1925).

A short explanation of the use of graphical methods of facilitating the calculations commonly involved in radio circuits.

R141.—Aerial Tuner Design.—W. B. Medlam, B.Sc., and U. A. Oschwald, B.A. (*Exp. W.*, July, 1925).

Concluding part of a paper dealing analytically and practically with relation between the electrical constants of an aerial, the input impedance of the receiver to be operated and the design of the aerial tuning arrangements.

R144.—Iron Losses at High Frequencies.—Prof. G. W. O. Howe (*Electn.*, 12th June, 1925).

An expression is developed for the energy loss per unit volume in a lamination of given thickness, permeability and resistivity. The formula shows that the eddy current loss is directly proportional to t and inversely proportional to $\sqrt{\mu\rho}$, where t is the thickness of the lamination, μ the permeability and ρ the resistivity.

R149.—The Rectification of Small Radio Frequency Potential Differences.—F. M. Colebrook, B.Sc. (*Exp. W.*, July, 1925).

A paper read recently before the Radio Society of Great Britain. The work summarised has special reference to crystal detectors.

R300.—APPARATUS AND EQUIPMENT.

R329.—A Special Short-Wave Antenna.—G. W. Pickard (*Q.S.T.*, June, 1925).

An ingenious aerial system devised by H. Beggerow is described. A pair of Lecher parallel wires act as a closed feeder from the oscillator; at the far end one of the wires projects half a wave-length beyond the end of the other and therefore acts as an isolated half-wave radiator.

R342.5.—Power Amplifiers in Transatlantic Radio Telephony.—A. A. Oswald and J. C. Schelleng (*Proc. I.R.E.*, June, 1925).

A paper describing the development of a 150-kilowatt (output) radio frequency amplifier installation built for transatlantic telephone tests. The single side-band system of telephony is described with particular reference to its bearing on the design of the apparatus used.

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R343-4.—ETUDE OSCILLOGRAPHIQUE DE LA SUPER-REACTION.—M. M. David, Dufour and Mesny. (*Onde Elec.*, May, 1925).

A study of the Armstrong super-regenerative receiver. The writers have worked with this type of receiver on wave-lengths from 450 metres, down to 2 metres. They find no support for the conclusion arrived at by other investigators that the amplification increases as the square of the frequency of the received signal. If the supposition were correct, the amplification on 2 metres would be something incredible. As it is, the writers find that below about 50 metres the amplification is more or less constant. Super-regeneration ceases to be effective on wave-lengths somewhat higher than 450 metres owing to insufficient difference between the quenching frequency and the frequency of the incoming signal. Around this transition point one would naturally expect a rapid variation of amplification with wave-length, but, as stated, this variation falls off below a certain wave-length. Some most interesting oscillograms are reproduced which show how the oscillations start and stop when a signal is present and when no signal is arriving. The spasmodic bursts into oscillation in the latter case are very well shown, these being due to parasitic effects and giving rise to the "mush" so familiar in receivers of this type. For their experiments the writers have favoured the type of super-regenerative receiver in which the quenching oscillations of about 10 000 per sec. modulate the anode supply to the regenerative detector. As a source of signals for the experiments a transmitter capable of being modulated by a microphone was placed in another room. One set of oscillograms was obtained on a rotating drum by means of a cathode-ray oscillograph, the horizontal base-line being provided by an auxiliary controlling frequency of about 500 cycles, while the ordinates are controlled by the H.F. grid potential acting on the cathode beam to produce vertical displacements. This set of oscillograms only shows the envelopes of the H.F. oscillations, the individual oscillations being too close to be registered separately. In order to obtain traces of the individual H.F. oscillations another set of oscillograms was taken in which the horizontal auxiliary frequency was 273 000 per second. It is found that different adjustments may be necessary for receiving C.W. and telephony. Some adjustments give a response almost independent of the amplitude of the incoming signal; such adjustments would be very good for C.W. reception but would be useless for receiving a modulated transmission. The conditions for receiving the latter are discussed in the paper. It would appear that the amplification obtainable is only limited by the parasitic noises.

R376.3.—THE MOTIONAL IMPEDANCES OF AN ELECTRO-DYNAMIC LOUD SPEAKER.—A. E. Kenelly (*Q.S.T.*, June, 1925).

An abstract of a paper by Prof. K. Kurokawa of Waseda University dealing with the type of loud speaker in which a moving coil carrying the signal currents is suspended in a strong radial magnetic field. By a bridge method the impedance of the moving coil was measured at various audio frequencies and under various conditions of acoustical loading. Some resulting motional resistance-reactance diagrams are given.

R382.1.—THE HIGH-FREQUENCY COPPER LOSSES IN INDUCTANCE COILS.—S. Butterworth. M.Sc. (*Exp. W.*, July, 1925).

An article dealing with losses due to skin effect and eddy-currents.

R382.—WHAT SIZE OF WIRE?—F. J. Marco (*Q.S.T.*, June, 1925).

A number of coils all having the same inductance (suitable for the broadcasting band) were constructed in different dimensions and of different gauges of wire with a view to finding which would have the lowest average resistance over the broadcasting band of wave-lengths. For longer wave-lengths gauges 20 to 24 (American) has a slight advantage over thinner gauges but this advantage is relatively smaller on lower wave-lengths. The space occupied by a coil is an important practical consideration in the design of commercial receivers. For a given volume occupied by the coil, spaced winding of finer wire gives better results than close winding with thick wire. Generally speaking, there is not much to be gained by using wire thicker than 26 or 28 gauge. A heavy coating of dope consisting of collodion dissolved in amyl acetate is stated to have absolutely no measurable effect on either the resistance or distributed capacity of even the best inductances. Double silk covered wire was used in making up all the coils measured.

R400.—SYSTEMS OF WORKING.

R412.—PRODUCTION OF SINGLE SIDEBAND FOR TRANSATLANTIC RADIO TELEPHONY.—R. A. Heising (*Proc. I.R.E.*, June, 1925).

This paper describes in detail the equipment and circuit used in the production of the single side-band for transatlantic radio telephony in the experiments at Rocky Point. The set consists of two oscillators, two sets of modulators, two filters and a three-stage amplifier. The oscillators and modulators operate at power levels similar to those used in high-frequency communication on land lines. The three-stage amplifier amplifies the side-band produced by these modulators to about a 500-watt level for delivery to the water-cooled valve amplifiers.

The first oscillator operates at about 33 700 cycles. The modulator is balanced to eliminate the carrier, and the first filter selects the lower side-band. In these transatlantic experiments the second oscillator operated at 89 200 cycles, but might operate anywhere between 74 000 and 102 000 cycles. The second modulator, which is also balanced, is supplied with a carrier by the second oscillator and with modulating currents by the first modulator and first filter. The second filter is built to transmit between 41 000 and 71 000 cycles, so that by varying the second oscillator, the resulting side-band, which is the lower side-band produced by the second modulating process, may be placed anywhere between these two figures. Transmission curves for the filters are given as well as some amplitude-frequency performance curves of the set.

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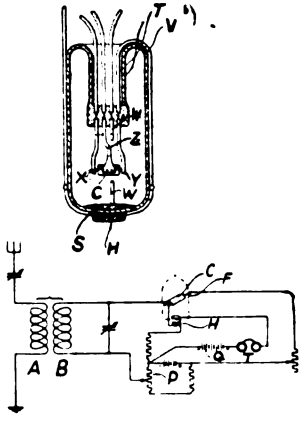
(The following notes are based on information supplied by Mr. Eric Potter, Patent Agent, Lonsdale Chambers, 27, Chancery Lane, W.C.2.)

[R008

THE ORIGINAL SODION.

(*Convention date, U.S.A., 1st December,* 1922. No. 207,818.)

The construction and connections of the early sodion detector are described in the above British Patent by the Connecticut Telephone and Electric Company Incorporated, and H. P. Donle. Referring to the illustration of the valve it will be seen that it consists of a glass vessel *V* provided with a re-entrant tube *T*. The end of this re-entrant tube carries four supports, which are sealed through in the ordinary manner. A filament is held between *X* and *Y* while the support *Z* carries a U-shaped collector *C*, which surrounds the filament. The support *W*, which is shown discontinuous for the sake of clearness, communicates with a quantity of sodium *S*, which rests on the bottom of the valve. It will be noticed that the filament lead *Y* is continued round the side of the valve to a heater *H*, consisting of a quantity of resistance wire. Thus it will be seen that on connecting the filament battery the current passes through the filament and through the heater coil, the object of which is to maintain the liquid sodium at a desired temperature. Referring now to the circuit diagram, it will be seen that a loose coupled aerial circuit *A B* is employed. The coupling is much looser than is usual with a valve receiver. The secondary circuit *B* is connected between the filament, or, rather, the potentiometer, and the U-shaped collector. The potentiometer *P* provides the collector *C* with a negative potential, while the H.T. battery *Q* is connected through telephone receivers to the liquid anode in the normal manner.



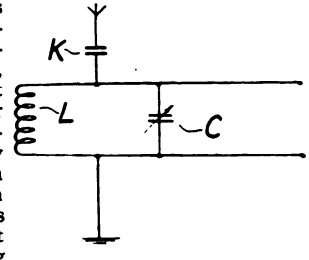
The operation of the device is exceedingly complicated. Briefly, there are two streams of current, one between the filament and the anode, and the other between the filament and the collector. Part of this latter current is neutralised by the negative potential supplied by the potentiometer *P*. Thus the device may be considered as operating by virtue of a pulsating current between the filament and the collector. This has a very small amplitude and is of a frequency of the order of 100 000 per second.

When radio frequency potentials are applied to the collector, there is a substantial fall in the average value of the collector current. The average value in the anode circuit follows the audio frequency variations in the collector current, and hence the telephones, or communication means included in that circuit are proportionally affected. The operation involves several electronic and ionisation phenomena. The sensitivity of the device is exceedingly good, increasing both with weak signals and with signal frequency.

AN OBVIOUS CIRCUIT.

(*Application date, 1st November,* 1923. No. 232,659.)

J. Scott-Taggart describes an aerial circuit arrangement in British Patent No. 232,659, one arrangement of which is shown in the accompanying illustration. The object of the invention is to provide a broadcast receiver which is practically independent of aerial capacity. For example, it will be seen that a broadcast receiver can be roughly calibrated and suitably adjusted, and can then be used on aerials of various capacities without any trouble arising when in the hands of an inexperienced operator. Referring to the diagram it will be seen that an ordinary aerial tuning circuit LC is provided, and the invention consists merely in inserting another condenser *K* in the serial lead. The capacity of this condenser is preferably less than that of the aerial, and for a broadcast receiver it is stated that it may be of the order of 0.0001 μF. We were under the impression that arrangements of this description had frequently been employed ever since tuning was introduced into wireless transmissions. In fact, we thought it was a common practice to employ a fixed series condenser in the



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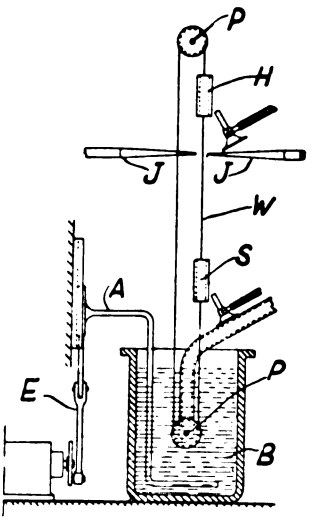
manner indicated. This arrangement has been actually used in certain broadcast receivers for a considerable time. It would appear therefore that the patent would be exceedingly limited in its nature.

COATING FILAMENTS.

(*Application date, 12th November, 1923. No. 233,374.*)

An interesting method of coating filaments is described by W. R. Bullimore in British Patent No. 233,374. The invention consists in coating a metallic core with an agglutinant, and subsequently dissolving the agglutinant by a solution containing in suspension the desired coating material.



One method of carrying this into effect is indicated in the accompanying illustration. Two pulleys *P* drive a wire *W* in band formation, which comprises the filament core. Two jets *J* coat the wire as it passes with a solution, for example, of celluloid. The wire passes through a heating tube *H*, which serves to dry the celluloid solution. The wire then passes through a bath *B* containing a solution of some substance such as amyl acetate, which contains in suspension salts or oxides of barium, strontium, or similar materials. An agitator *A* driven by an eccentric device *E* serves to maintain the coating material evenly in suspension in the amyl acetate.

The wire then passes through a tube *S* of silica or similar material which is heated sufficiently to dry off the solvent and burn off the celluloid, but not so strongly as to injure the oxide coating. The cycle of operation is then repeated until a sufficiently thick coating has been applied to the wire.

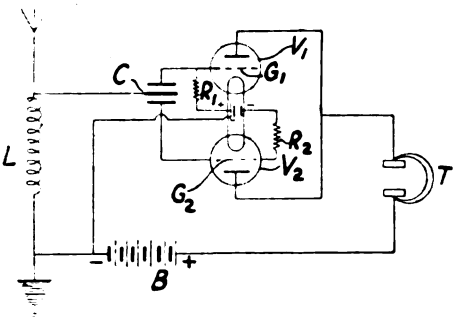
A FULL-WAVE RECTIFICATION IDEA.

(*Application date, 22nd January, 1924. No. 232,672.*)

British Patent No. 232,672, granted to D. S. B. Shannon, gives details of a rectification scheme. It is stated that the object of the invention is to rectify both the positive and negative half-cycles of a wave.

The suggested scheme is shown in the accompanying illustration. An aerial circuit containing, for some reason, merely an inductance *L*, is shown coupled between the filaments of two valves V_1 and V_2, and the middle plate of a double condenser *C*. One half of the condenser is connected to G_1, while the other half is connected to G_2. G_1 is connected by a low resistance R_1, to the positive side of the filament battery, while G_2 is connected by another low resistance R_2 to the negative side of the filament battery. Both anodes are connected together, and are supplied by a high tension battery *B* through a pair of telephones *T*.

It is stated that by making one grid positive and the other grid negative with respect to the filament,



full wave rectification will be obtained, but we do not quite follow, in the inventor's explanation, how this is brought about. It is certainly new to us that a positive potential on the grid will rectify positive half-waves, while a negative potential will rectify negative half-waves. When a radio frequency potential is applied between the filament and the common point of the double condenser, both grids will be of substantially the same R.F. potential with respect to the filament.

The specification does not say how the valves are intended to rectify. In any case, if the grids become positive with respect to the filament—and this must occur simultaneously with both the valves—there will be either an increase or a decrease of anode current through the telephones; whereas, if the grids become simultaneously negative, the opposite effect, or nothing at all, will result, according to the manner in which the valves rectify: *i.e.*, as bottom bend rectifiers, or by virtue of accumulative grid rectification. We are of the opinion that the scheme as stated is fallacious.

FILAMENT CONSTRUCTION.

(*Application dates, 12th November, 1923, and 12th November, 1923. No. 233,375.*)

A form of filament is described by W. R. Bullimore in the above British Patent. This form, it is stated, has a comparatively large diameter in relation to its resistance, whereby greater mechanical strength and emissive surface are obtained without increase of temperature or current consumption. A further feature of the invention is the provision of an active emissive coating which will remain united to the filament.

The invention really consists in coating a core of refractory metal or alloy, of relatively high specific resistance and melting point, with a "noble metal," *i.e.*, one which does not tarnish under ordinary conditions. The filament may be produced, for example, by nickel chrome alloy with platinum; or alternatively a molyndenum or tungsten wire may be coated with platinum or palladium. For example, platinum may be deposited by passing the core through a bath of ammonium platino-chloride salt.

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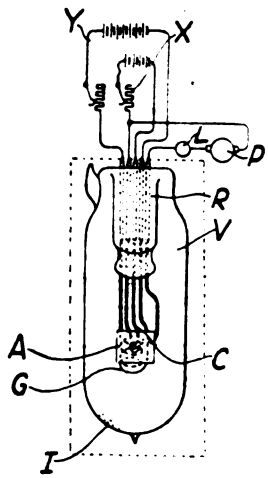
A further feature of the invention is to coat a wire of this description by passing it through a bath containing nitrates of alkalis and alkaline earth metals. Fairly explicit details are contained in the specification.

A "GENODE" DEVICE.

(*Convention date, U.S.A., 21st December, 1922. No.* 231,188.)

A very interesting device, in connection with which the term "genode" is introduced, is described by the British Thomson-Houston Company, Limited, K. H. Kingdon and I. Langmuir. The accompanying illustration shows one form of the device, which consists essentially of an anode and two incandescent filament cathodes.



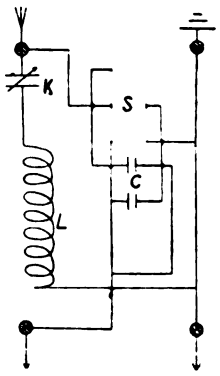
A glass or other tube *V* contains a re-entrant tube *R*, which has sealed into it four supports. Two leads go to an ordinary cathode *C* consisting of a coiled filament of tungsten. This is heated by the circuit *X* consisting of a battery and a resistance. Surrounding the cathode is a cylindrical anode *A*, and between the cathode and the anode is a source of power *P* and a load *L*. Another coiled tungsten or nickel filament *G*, constituting the genode, is placed between the cathode *C* and the anode *A*. The genode is also provided with a heating circuit (*Y*) consisting of a battery and resistance. Means are provided for the generation of positive ions, and before any suitable substance is introduced the electrodes are freed from occluded gases. After evacuation a material having in the gaseous state a low ionising potential is placed in the valve. A member of the alkali group such as cæsium or rubidium is shown at *I*. The vapour pressure of the ion-generating material may be controlled by an external heater, as indicated by the dotted outline round the valve.

This somewhat resembles the sodion, which is described in these columns, and the device functions by a somewhat similar process. When the cathode is heated to incandescence, electrons are emitted, and when a potential is applied between the anode and the cathode from the source *P*, as is indicated, pure electronic current will be set up, the value of which is determined and limited by the space-charge. When the genode is heated to obtain a generation of positive ions, the opposition to the flow of electron current by the space-charge is reduced, and with sufficient generation of ions the space-charge effect is substantially eliminated. It will be noticed that the genode circuit has no definite potential difference with respect to the other electrodes, which is an interesting feature.

A WAVE TRAP.

(*Application date, 5th December, 1924. No.* 232,877.)

A wave trap is described in the above British Patent by M. A. Hutchins. It is stated that the invention incorporates a trap comprising a tuned rejector circuit consisting of a plug-in coil and a variable condenser connected in series, in conjunction with a small-value fixed condenser in parallel. A circuit is placed across the tuned circuit of the receiver, and adjusted to the wave-length of the interfering station. It is stated that the difference in wave-length occasioned by the use of the trap is neutralised by one or more fixed condensers.

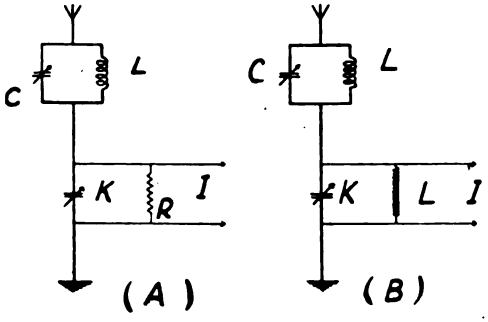


Referring to the accompanying illustration these are shown at *C*, and are adapted to be connected by a switch *S*. The traps appear to consist of a condenser *K* and an inductance *L*. We fail to see exactly what the novel point of the invention is, and the circuit diagram is not at all clear. A circuit consisting of an inductance and a capacity in series is more usually known as a series-acceptor circuit, and not a rejector circuit.

FILTER CIRCUITS.

(*Application date, 19th February, 1924. No.* 233,802.)

A form of filter circuit is claimed in the above British Patent by D. H. McDonald. Two arrangements are shown in the accompanying illustration. In the aerial lead to receiver is included a tuned circuit *LC*, while the input *I* to the receiver is connected across another variable condenser *K*.



It is stated that by suitably adjusting the two condensers *C* and *K* any undesired signal can be eliminated, and the desired signal tuned in. It will be noticed that in one arrangement (A) a resistance *R* is connected across the input and across the condenser *K*, while in another form (B) a choke *L* is employed.

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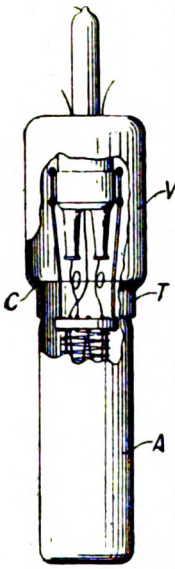
So far as the arrangement *B* is concerned there appears to be very little novelty about it. The use of a series-tuned circuit *LC* for the purpose of eliminating undesired wave-lengths has been known for years, and the input arrangement as shown at (A) or (B) has also been known for many years. It would appear that the substance of the patent is limited to the combination of the two schemes.

A COPPER-GLASS SEAL.

(*Convention date, U.S.A., 21st April,* 1923. *No.* 214,584.)

An interesting copper-glass seal is described by the Western Electric Company, Limited, and W. G. Housekeeper in the above British Patent. In previous copper-glass or similar seals it was customary to give the metal a very thin edge at the sealing point. A totally different method is illustrated by the accompanying diagram, which shows a valve employing a seal of the type we describe.

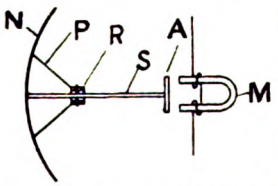


The vitreous portion *V* of glass or silica is provided with a tubular-shaped end *T* having cylindrical walls. A metal anode *A* is also provided with a thin cylindrical end *C*, and is arranged so that it slides into the cup-shaped end of the vitreous portion *T*, the end of the copper projecting beyond that portion. The seal is made by heating the vitreous portion in the neighbourhood of *T*, which compresses it round the thin end of the copper tube *C*. It is stated that a seal of this description remains vacuum-tight up to the fusion point of the glass or silica. We should imagine that it would be infinitely more rigid and is mechanically stronger than the previous types.

A "ROUND" LOUD-SPEAKER.

(*Application date, 19th November,* 1923. *No.* 229,382.)

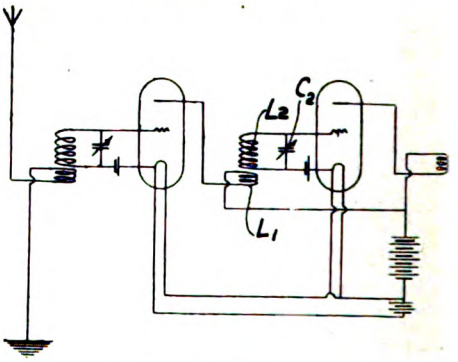
Captain H. J. Round describes in British Patent No. 229,382 the construction of a loud-speaker movement which is illustrated by the accompanying diagram. The loud-speaker is of the hornless type, and is built up in a similar manner to an umbrella or parasol. Thus, referring to the illustration, it will be seen that a main stick *S* is provided, which passes through a runner *R*. The runner *R* has attached to it a number of stretchers *P*, which are joined to a concave area *N*, built up of a number of radial supports covered with material such as paper or varnished silk. The end of the stick *S* is provided with an armature *A* which is operated by an electro-magnet *M*. The electro-magnet, of course, is fed with audio-frequency currents in the usual manner. The invention also provides for energising the stick mechanically, electrostatically, or by a magneto-striction device.



A RADIO FREQUENCY COUPLING.

(*Application date, 4th February,* 1924. *No.* 233,053.)

Some fairly extensive details of a radio frequency coupling device are described in the above British Patent by W. Rawsthorne. The accompanying diagram illustrates the arrangement of the circuit, which, it will be seen, is more or less normal. The object of the invention is to provide a radio frequency coupling device which can be used with a multi-stage amplifier without any tendency to produce oscillations. The novelty of the invention lies essentially in the coupling device, or radio



frequency transformer. This is wound so that both the primary and the secondary have a small self-capacity; and also the windings are arranged so that the capacity between them is reduced to a minimum. For a wave-length of the order of 350 metres it is suggested that a transformer may be wound on a former having a diameter of 7 centimetres and a primary winding (L_1) of 25 turns of 30 S.W.G. wire with a secondary (L_2) of 90 turns of the same gauge. The secondary winding L_2 is tuned by a condenser C_2. The ratio of the inductance of the primary and secondary windings is roughly 1 : 10.

An explanation is put forward in the specification which accounts for the operation of the circuit, but we are not altogether in agreement with the statements. In another form the primary and secondary are wound as ring coils, one being within the other. An important feature of the arrangement is that the primary winding is placed nearest the earthed end of the secondary winding.

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EXPERIMENTAL WIRELESS & The WIRELESS ENGINEER

VOL. II. SEPTEMBER, 1925. No. 24.

Editorial Views.

The Institution.

IN our last issue we discussed, on this page of "Editorial Views," the proposal to found a technical institution for wireless engineers.

Since then there has been a conference between Mr. James Nelson, M.I.E.E. (on behalf of the proposed new body) and the Committee of the Wireless section, I.E.E., and the latter have issued a statement, which we reproduce practically *in extenso* herewith (the omissions are purely to save space, and do not affect the points at issue).

31st July, 1925.

Recent correspondence in the Press indicates that there is some misconception as to the eligibility of wireless engineers for membership of the Institution, and it is therefore necessary to state that it is possible for an engineer to become a member of the Institution with qualifications of a purely wireless nature.

For the admission of Wireless Engineers to the class of Associate Member (A.M.I.E.E.), it is necessary, in addition to the possession of adequate professional experience for a period of at least two years, in the case of those who do not possess an exempting examination qualification, or do not submit a satisfactory thesis, to pass the A.M.I.E.E. Examination in the following subjects . . .

The Committee of the Wireless Section of the Institution have recently considered the above syllabus and they are of opinion that it represents the minimum amount of professional knowledge which a qualified Wireless Engineer should possess. No conditions are laid down by the Institution as to how or where an applicant may have obtained his training.

In order to become a member of the Wireless Section of the Institution it is necessary that the member of the Institution shall be actively engaged in the study, design, manufacture, or operation of wireless or high-frequency engineering apparatus. The meetings of the Wireless Sections are not, however, confined to members of the section, but are open to all members of the Institution. . . .

Some valuable suggestions have emerged from the recent correspondence, and will receive the careful consideration of the Section Committee, more particularly as regards the type and number of papers read, and as to increasing the activities of the Wireless Section outside London.

As regards the suggested formation of a new society, the Wireless Section Committee considers there is no need for it, because, as indicated above, wireless engineers can obtain membership of the Institution, while amateurs are already catered for by the Radio Society of Great Britain.

Frankly, we do not consider that this statement really clears up the difficulty. The examination is known to be quite a reasonable one, but one of the difficulties

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is the definition of "adequate professional experience." It is alleged that the I.E.E. Membership Committee have not the qualifications to judge what constitutes this in the case of wireless engineers pure and simple, and that cases have occurred which look like discrimination against wireless experience. Again, applicants have, it is said, offered to submit a thesis as a proof of knowledge, and these offers have been refused.

Again, it is clear that any Member of the Institution *can* become a member of the Wireless Section without necessarily having any wireless knowledge at all, which is resented, as indicating that the Institution attaches no importance to pure wireless knowledge.

In fact, it seems that in spite of the conference, there is still a good case for the existence of a new body, which, it is hoped, may eventually fuse with the Institution, or at any rate work in close co-operation with it.

Two points, however, seem to us necessary in the forming of any such body :—

(1) The qualifications for membership must be fairly high—approximately equal to those of the I.E.E., but Wireless.

(2) The supporters and founders must be prepared to claim no special privilege, but be assessed for membership on their merits like all other members.

We, ourselves, although we are in support of the general idea of such a new institution, are not prepared at the present moment to express ourselves either for or against the one which is actually being organised at the present moment. Our support will depend on our being convinced that the formation is proceeding on the lines we have just suggested.

Daventry.

Our readers may be surprised that there is no article in this issue describing the new 25kW. station at Daventry. We feel, however, that nothing but a complete and detailed account of the circuit and components (such as the account of Chelmsford in our issue of September, 1924) will suffice for our readers, and we therefore propose to defer consideration of it for a little while. It is more than likely that as the result of actual experience in operation some little changes will be made here and there in the arrangements, and we wish to deal with the final assembly when we describe it.

One may, however, make a few general remarks. Substantially, the station is a repetition of Chelmsford, but on a permanent basis and with careful arrangements throughout to allow for expansion up to 60kW. if necessary. At present about 25kW. is applied to the anodes of the main amplifier, 20kW. of H.F. power goes to the aerial circuit, and about 12kW. is actually radiated.

The daily papers report bad signals in Essex, but this hardly seems to be confirmed by the reports in the hands of the B.B.C. Elsewhere, the station seems to give excellent results. At our own stations, in the heart of London, it comes in at almost exactly the same strength as Chelmsford (by measurement of carrier wave aerial current), although on the basis of output power and distance, it should be only half as strong. It would appear that Chelmsford must have been blanketed to some extent.

Although Daventry is a highly effective station, the total power input figures throw an interesting light on the necessity of sacrificing pure efficiency when fine quality is required: in order to put out that 12kW. or so of modulated waves, about 100kW. of input power is used!

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Some Measurements on Wireless Wave-Fronts.

By R. L. Smith Rose, Ph.D., M.Sc., A.M.I.E.E., and R. H. Barfield, M.Sc., A.C.G.I. **[R113·9**

I. Preliminary Theory and Previous Work.

(a) *Elementary ideas of radiation of waves from an aerial.*

IN the study of the propagation of electromagnetic waves through space, whether from the mathematical or physical point of view, the student usually encounters at the outset a diagram of the sort indicated in Fig. 1, which represents the distribution of the electric and magnetic fields in the neighbourhood of a straight-wire Hertzian oscillator. During the period when an alternating current is flowing in the oscillator there is present a rapidly varying electric field the lines of force of which lie as shown in radial planes intersecting in the wire oscillator, and also a similarly varying magnetic field, the lines of force of which are circles concentric with the wire and in planes perpendicular to that of the wire. In converting this ideal theoretical case to that of a vertically arranged aerial connected to earth, the latter is assumed to be of infinitely high conductivity so that an image of the aerial is formed therein, completing the Hertzian oscillator the field of which is bisected by the earth's surface as the equatorial plane. The process of radiation of waves from such an aerial is then depicted in the manner of Fig. 2, in which the half-loops of electric force accompanied by the concentric circles of magnetic force are shown being thrown off from the aerial at each period of oscillation. It will be seen that at a distance of a few wave-lengths from the aerial (as at point *P*) the electric field at the earth's boundary surface is vertical, and the magnetic is horizontal and perpendicular to the direction of travel of the wave. Further consideration of the mode of travel of these fields shows that they are both strictly in phase, *i.e.*, at any point both

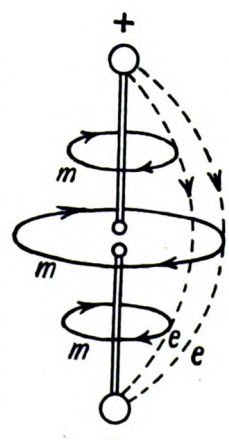

Fig. 1.

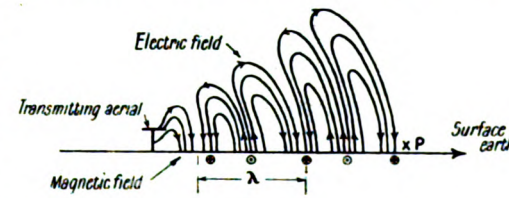

Fig. 2.

fields pass through their maximum and zero values at the same instant, these two extremes of amplitude being separated in time by a quarter of the period of the oscillations in the aerial and in space by a quarter of the length of the waves produced. The quotient of the wave-length divided by the period of oscillation gives the velocity of propagation of the waves.

Now the surface which contains both the electric and magnetic fields is termed the wave-front of the advancing wave. In the case depicted in Fig. 2, the wave-front at the earth's surface will be a vertical cylinder concentric with the aerial. In considering a portion of this wave-front it may be regarded as plane for most practical purposes over an area whose side subtends an angle of less than one tenth of a degree at the aerial. Thus at a radius of one mile the wave-front will be sensibly plane over an area three yards square, and at greater distances this area may be increased proportionally. Further consideration of the spreading-out of the fields of the wave radiated from the aerial will show that at all points in the space surrounding the aerial the direction of propagation of the energy of the wave is perpendicular to the wave-front. The three directions of the electric and magnetic

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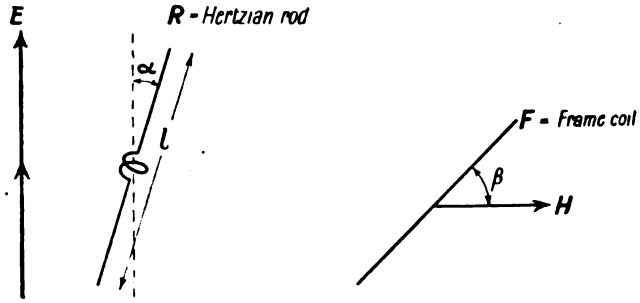
fields and of the propagation of the wave are thus mutually at right angles.

(*b*) *Determination of wave-fronts with aerial and loop.*

Now in studying the action of a receiving circuit or other obstacle placed in the path of such a radiated wave, the effects of either the electric or the magnetic fields may be considered with precisely the same result. It is usually convenient, however, to consider the action of the electric field when using an open aerial receiving arrangement and of the magnetic field when using a closed coil receiver. This will be apparent by reference to Figs. 3 (*a*) and (*b*). If E is the maximum intensity of the vertical electric field due to the wave in Fig. 3 (*a*) and a straight aerial of length "l" is placed in the field at an angle "α" to the vertical, the



(*a*) Fig. 3. (*b*)

maximum value of the electromotive force induced in the aerial is $E \cos \alpha$. In Fig. 3 (*b*) F represents a plan view of a vertical loop of area "A" in the magnetic field of maximum intensity H, the plane of the loop making an angle β with the magnetic field. The electromotive force induced in each turn of the loop has a maximum value of $AH2\pi n \cos \beta$, where "n" is the frequency corresponding to the wave.

It is evident from these considerations that the directions of the electric and magnetic fields can be determined by means of a rotating straight wire aerial and a rotating loop respectively. For if the aerial wire in Fig. 3 (*a*) be turned until no E.M.F. is induced therein, and consequently no signal received from the arriving wave, then $E\, l \cos \alpha = O$, and hence $\alpha = 90°$; which means that the electric force is perpendicular to the aerial wire. Similarly, if the loop is rotated until the signal passes through zero or a minimum of intensity the magnetic field is then parallel to the plane of the loop. For the complete definition of the directions of these fields in space of three dimensions it will be necessary to carry out this rotation of the Hertzian rod and frame coil respectively about two axes perpendicular to each other.

(*c*) *Previous work on this problem.*

For the determination of the wave-front of an electro-magnetic wave, it is thus necessary to obtain the directions of both the electric and magnetic forces. In the case of a single plane wave the determination of these forces is rendered possible by the aid of two separate receivers, one a straight open aerial and the other a closed loop, either of which can be set parallel to any plane in space.

Previous work in this direction has been carried out by Austin,[1] who used a straight Hertzian rod to determine the electric field; by Erskine-Murray and Robinson,[2] who used a Hertzian rod and a frame coil mounted on three axes for determining the direction of propagation of electro-magnetic waves; while Bellini[3] has experimented with a tilting frame coil in an attempt to measure the angle of arrival of the downcoming wave which is supposed to be responsible for night errors on direction-finders. Sir Henry Jackson[4] also has carried out experiments with a tilting frame coil, particularly with a view to investigating night errors in wireless bearings. As far as can be gathered from the published information however, these experiments were accompanied by either instrumental or local errors which prevented the establishment of any definite facts relevant to the general problem of the propagation of waves.

---

[1] L. W. Austin.—"The Wave-Front Angle in Radio-Telegraphy."—*Journal, Washington Academy of Science*, 1921, Vol. 40, pp. 101-106.

[2] J. Erskine-Murray and J. Robinson.—"An Improved Method for Determining the Direction of Propagation of Electromagnetic Waves." British Patent 176, 127/1921.

[3] E. Bellini.—"Frame Aerials and Errors in Bearings."—*Electrician*, 1922, Vol. 89, pp. 150-1.

[4] H. B. Jackson.—"Directional Effects with Frame Aerials."—*Wireless World and Radio Review*, 1922, Vol. 1, 9, pp. 789-800.

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(*d*) *Notation employed.*

For the sake of brevity and clarity of expression in the present paper the following notation has been adopted, which is, as far as can be ascertained, in accordance with accepted practice :—

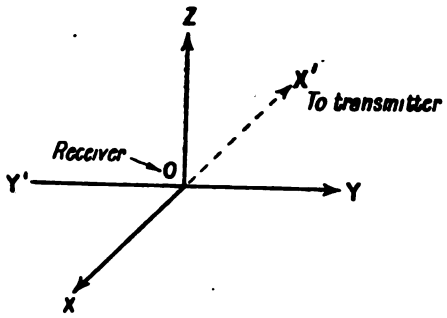

Fig. 4.

(i.) Due to the action of a transmitting station by the agency of one or more separate waves : E is the resultant electric force and H is the resultant magnetic force at a receiver.

(ii.) Rectangular axes are employed as in Fig. 4 with the receiver at the origin and arranged so that : OZ is vertically upwards ; OX is horizontal and is the great circle through the transmitter measured in the direction away from the transmitter ; OY is horizontal perpendicular to and to the left of OX.

(iii.) The plane XOZ is conveniently termed the plane of propagation of the waves.

(iv.) Angle "α" is the inclination of E to the vertical in the plane YOZ, *i.e.*, perpendicular to the plane of propagation: see Fig. 4 (*a*).

Angle "β" is the inclination of E to the vertical in the plane of propagation (XOZ) : see Fig 4 (*b*).

Angle "γ" is the inclination of the horizontal component of H to $O\gamma$; *i.e.*, "γ" is the error in apparent bearing of the arriving waves : see Fig. 4 (*c*).

Angle "δ" is the inclination of H to the horizontal plane : see Fig 4 (*a*).

(v.) A wave is considered to be "vertically" polarised when E is in the plane of propagation ; *i.e.*, when $\alpha = \delta = O$.

(vi.) A wave is considered to be "horizontally" polarised when E is perpendicular to the plane of propagation ; *i.e.*, $\alpha = 90°$, $\beta = O$.

In the next section of the paper, experimental methods of determining the directions of E and H are described with typical results obtained at the Slough Station of the Radio Research Board.

II. Determination of the Directions of the Electric and Magnetic Fields at a Short Distance from a Transmitting Station.

The apparatus employed at the Radio Research Board's Station at Slough, for the determination of the directions of the forces in the wave arriving at a receiving station, makes use of the principle outlined in Section I (*b*) above.

(*a*) *Determination of the direction of the electric field with a hertzian rod.*

A straight Hertzian rod type of receiver of 30 ft., length was built on a wooden tower 20 feet above the ground, the rod being capable of a setting in any direction in space by rotation about both horizontal and vertical axes. A view of the receiver is shown in the photograph, Fig. 5 and a diagram of connections in Fig. 6.

Leads from the centre of the rod are taken into coupling coils and an amplifier contained in a screened box supported on the centre

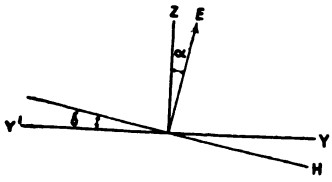

Fig. 4a.

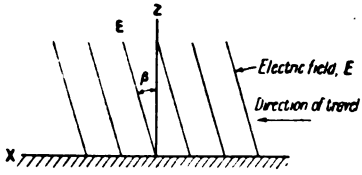

Fig. 4b.

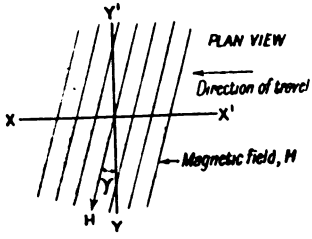

Fig. 4c.

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turntable. The success and accuracy of the receiver are largely due to the efficiency of the screening of all apparatus and leads, except the actual wire forming the rod ; and in the present arrangement this screening is

Fig. 5.

so satisfactory that when using a nine-valve amplifying receiver there is no direct pick-up of signal from any transmitting station.

In making an observation, the horizontal axis of rotation of the rod is first pointed away from the transmitting station, *i.e.*, along OX, and the beam rotated in the plane ZOY until the received signal is reduced to zero, in which position the angle "α" made by the rod with the horizontal is observed on a scale. The horizontal axis is then turned through a right angle to be parallel to OY, and the rod is rotated in the plane of reception ZOX, and the zero position again observed to obtain the angle "β." The direction of the electric field is then the normal to the plane containing the directions of the rod in the above zero positions. In each position the observation is repeated after reversal of the leads between rod and receiver, and the readings are also repeated with an orientation of the rod along the axes OX' and OY'. This process practically eliminates any errors due to direct pick-up of signals and due to the scales.

(*b*) *Determination of the direction of the magnetic field with a tilting coil.*

This measurement is carried out with the aid of a frame coil capable of rotation about both vertical and horizontal axes. With its plane vertical the coil is rotated to the minimum signal position, and the ordinary wireless bearing observed. The plane of the coil in this position is then parallel to the horizontal component of the magnetic field of the arriving wave. The coil is now turned through 90° about its vertical axis to the maximum signal position. It is then rotated about its horizontal axis until the position of zero signal is found, when the angle made by the coil with the horizontal is observed. This reading gives the elevation "δ" of the resultant magnetic field due to the arriving wave, and the direction of H is the line of intersection of the planes of the coil in the two zero positions above determined. In the complete measurements the observations are always repeated after reversing the connections of the frame coil, and also after rotating the whole coil through 180° about a vertical axis. The mean readings so obtained are considered to be fairly free from any scale errors and also from the effects of any residual direct pick-up on the leads and coupling coils of the receiver.

As a check on the above method of determining the direction of H the frame coil can then be rotated about a third axis so

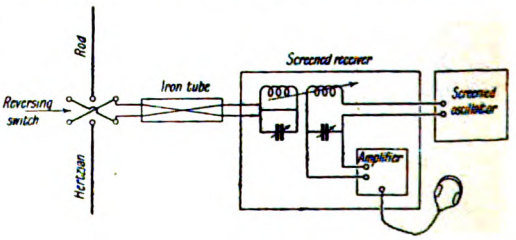

Fig. 6.

oriented in space as to be parallel to the line of intersection of the planes of the coil in the two minimum positions determined above. If complete rotation of the coil about this axis gives no signal, no magnetic force from the wave links the coil, and it must therefore be parallel to the axis

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of rotation. This method was first suggested by Erskine-Murray and Robinson and used by Sir Henry Jackson. Although the coil at Slough is provided with this third axis of rotation its use has so far been found unnecessary.

The receiving apparatus in this case is similar to that used with the Hertzian rod and it is completely screened from direct pick-up in the same mannner. In addition, the operator and the whole receiver, including the frame, are contained in a wooden hut which is well insulated from earth and entirely surrounded by a wire screen consisting of open untuned loops. This type of screen has been shown previously to eliminate antenna effect from the frame coil system. Views of the coil receiver and also of the exterior of the hut containing it are given in Figs. 7 and 8.

The accuracy of the observations made with both the rod and coil receivers is considered to be about 1.0°, although the mean of a number of readings is probably of a higher order of accuracy.

(c) *Results obtained at Slough.*

The four angular quantities, $\alpha, \beta, \gamma, \delta$, measured are considered to be of positive sign when, looking from O along either OX, OY or OZ, they correspond to a positive rotation of E and H from the axes OZ and OY respectively.

In the general investigation both the above sets of apparatus were used simultaneously and Table I. shows a summary of the results obtained.

TABLE I.

SUMMARY OF RESULTS OF SIMULTANEOUS MEASUREMENTS AT SLOUGH OF THE DIRECTIONS OF ELECTRIC AND MAGNETIC FIELDS AT SHORT DISTANCES FROM THE TRANSMITTER.

Transmitting Station.	Distance (miles).	Wave-length (metres).	Frequency (kc/sec.).	Direction of E.		Direction of H.	
				α (degs.)	β (degs.)	γ (degs.)	δ (degs.)
Northolt	9.0	6,900	43.5	+0.3	+0.7	+0.2	0.0
Ongar	36.0	3,800	79.0	+0.2	+0.7	0.0	+0.8
Teddington	11.5	2,600	116.0	—0.3	+0.6	—0.2	—0.1
,, ...	,,	750	400.0	—0.1	+2.1	+0.7	—0.3
,, ...	,,	750*	400.0	—0.1	+2.0	+1.0	0.0
,, ...	,,	450*	670.0	—0.3	+2.7	+0.9	0.0

* Indicates "spark" transmission; all others continuous waves.

In discussing the significance of these results it must be remembered that the limiting accuracy of the apparatus used is, as mentioned above, slightly under one degree for the average of a number of readings as summarised in the table. The results show that in all cases the electric force

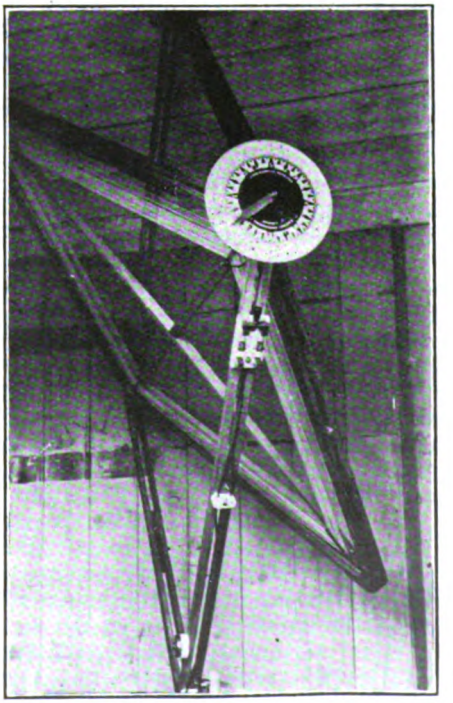

Fig. 7.

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lies in the vertical plane of propagation (*i.e.*, $\alpha = 0$) but that it is tilted forward by a small angle (β) the value of which increases as the wave-length is reduced. In a similar manner it is seen that the magnetic force is horizontal and perpendicular to the

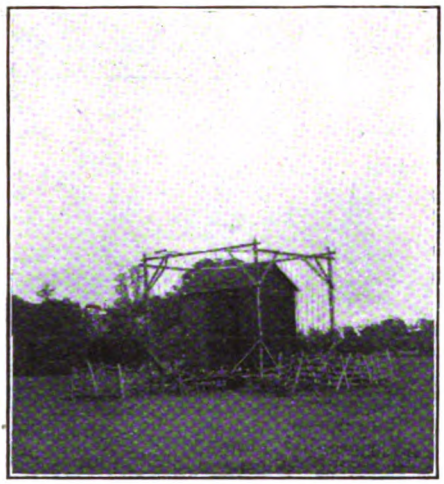

Fig. 8.

plane of propagation. Having thus determined the directions of the component forces, it is known that the wave-front, which is the plane containing these forces, is travelling in the direct line from transmitter to receiver, being slightly tilted forward in the direction of propagation.

Neglecting for the moment this small forward tilt of the electric field, it will be appreciated that the observed directions of the forces are those which would be expected from the brief consideration of the mode of radiation of wireless waves from an aerial given in Section I (*a*) and depicted in Fig. 2 above. In the course of the experiments the aerial at the Teddington transmitting station was altered at intervals to such typical standard forms as; a vertical "cage,"; a *T* aerial; and an inverted "*L*" type with the horizontal portion pointed first to the east and then to the west. None of these arrangements was found to produce any departure of the fields in the waves arriving at the receiver from their normal directions as indicated in Table I. While these undoubtedly represent the usual arrangements of aerials for transmitting purposes it might be asked whether some other arrangement could be constructed which would send off waves with the component fields oriented in a different manner. Partly with this object in view, two special experiments were carried out in this investigation, as described in the next section.

(*d*) *Special experiments in an attempt to obtain a horizontal electric field and a vertical magnetic field in a radiated wave.*

In the first experiment a large aerial tuning inductance, placed with its axis vertical, was used in the manner of a coil transmitter in an attempt to send off a wave with its magnetic field vertical instead of, as usual, horizontal. The inductance consisted of a helix of 42 turns of 6 ft. diameter, and by disconnecting the station aerial and substituting a dummy, a current of 36 ampères was obtained, giving 1 512 ampère turns. Used in this manner, the radiation from the coil as such should have its magnetic field vertical; but the signals received on a frame coil at Teddington at nine miles distance were quite sufficient for accurate direction finding down to one or two degrees, and the arriving waves were found to have a horizontal magnetic field within these limits. The waves were, in fact, exactly similar to those received from the transmitter when the aerial was radiating in the normal manner.

The second experiment involved the entire removal of the usual aerial at Teddington. For transmission purposes on this aerial an earth screen was normally employed, of dimensions 600 ft. × 150 ft., and erected horizontally at a height of about 9 ft. above the ground. This earth screen was cut laterally in two halves, which were joined up to the secondary coil of the spark transmitter to form a horizontal Hertzian oscillator. The natural wave-length of this arrangement was found to be about 800 metres, and by inserting a 1000$\mu\mu F$ series condenser this was reduced to the standard wave-length of 450 metres at which adjustment a current of 3-4 ampères could be obtained in the screen. The coupling between primary and secondary coils of the transmitter was made very loose, and, neglecting any effects of capacity connection to earth, the vertical portions of the "aerial" circuits were only one or two feet; even over this length the leads with current in opposite directions were run side by side

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with a spacing of a few inches. These distances are almost negligibly small by comparison with the dimensions of the screen (600 ft. × 150 ft.), and would appear to justify the assumption that the horizontally polarised radiation would at least be of the same order as that which is vertically polarised (the waves being assumed to be polarised in the direction of the electric force). When transmitting with such an arrangement the direction of the forces of the waves arriving at Slough were found to be similar to those in all previous cases.

In concluding this section, it may be mentioned that the signals received from this "screen aerial" were quite adequate for ordinary communication purposes at a station nearly 100 miles away.

III.—The Effect of the Earth's Conductivity on the Propagation of Electro-Magnetic Waves.

(*a*) *Zenneck's theory.*

In an elementary study of the mode of propagation of waves over the earth's surface it is usual to regard the earth as possessing infinite conductivity. It is well known that in this condition a high frequency electric current travels entirely on the surface, and that its passage along the conductor entails no loss of energy. A very little knowledge of the electrical properties of the materials comprising the earth's crust will show that these are very far from being perfect conductors. From this fact it follows that a high-frequency current will penetrate the conductor to an extent depending upon the frequency and the permeability and resistivity of the conductor.

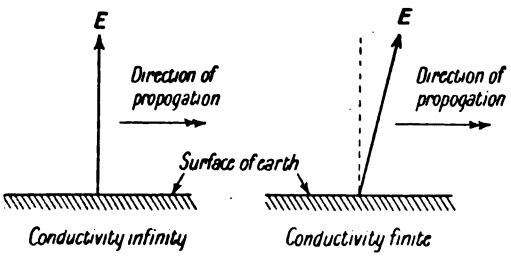

Fig. 9.

It will also be realised that the passage of current through a conductor of appreciable resistance must involve a waste of energy which must ultimately be drawn from the source of the current.

Now in 1907 Dr. J. Zenneck published the results of a theoretical investigation on "The Propagation of Plane Electro-magnetic Waves over a Plane Conducting Surface with reference to Wireless Telegraphy." Zenneck considered the case of a plane electro-magnetic wave travelling without divergence over a surface which is the boundary between two media (such as air and earth) of different conductivity and dielectric constant. It was shown that the passage of waves under such conditions necessitates that the electric field shall have an horizontal as well as a vertical component, the relative magnitude of these components depending upon the electric constants of the two media and on the frequency corresponding to the waves. From this condition it follows that the resultant electric field just above the earth's surface is not quite vertical, but is tilted forward slightly in the direction of propagation in the manner depicted in Fig. 9.

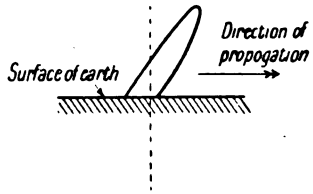

Fig. 10.

Now it was also shown in the theoretical investigation that only by certain combinations of conditions of the two media will the electric field be still represented by a straight line with such a forward tilt. In general, there is a difference of phase between the horizontal and vertical components of the field, so that the resultant electric force just above the earth is of elliptical rotating form, the plane of the ellipse coinciding with the vertical plane of propagation; as represented in Fig. 10.

Except in the case when the ellipse is very broad, the major axis of the ellipse is the more important in considering the effect of the electric field of the arriving wave. It is then evident that if the forward tilt of the axis is very marked, it will be advantageous, when possible, to arrange a receiving aerial to the same angle, in which position the E.M.F. induced therein will be greater than in a vertical aerial. It is therefore important to have some definite knowledge as to the probable value of this forward tilt in some of the cases likely to be met with in practice.

Returning now to the experimental results given in Table I above, it will be appreciated that the angle β measured is the

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angle by which the major axis of the ellipse departs from the vertical. For the conditions prevailing at the Slough Receiving Station, it is seen that whilst this angle is negligibly small on medium wave-lengths, its value increases to nearly 3° on a wave-length of 450 metres. The slight ellipticity

Fig. 11.

of the electric field was indicated in these experiments by the fact that when the Hertzian rod was rotated in the plane of propagation, the signal was never quite extinguished, whereas when rotated in the perpendicular plane, a perfect zero of signal was obtained.

(*b*) *Determination of the conductivity of the earth at Slough.*

In the paper referred to above, Zenneck showed that for a wave travelling over the surface of the earth, the ratio of the magnitude of the horizontal electric force (E_x) to that of the vertical electric force (E_z) is given by the equation

$$\frac{E_x}{E_z} = \sqrt{\frac{nK_1}{1+\frac{n^2K^2}{\sigma^2}}} \quad .. \quad (1)$$

where "n" is the frequency corresponding to the waves.

K_1 is the dielectric constant of the air.
K ,, ,, ,, ,, ,, ,, earth.
σ ,, ,, conductivity ,, ,, earth.

The two components E_x and E_z differ in phase by an angle "ϕ" where

$$\tan 2\phi = 2\sigma/nK.$$

These equations suffice to determine the ellipse which represents the electric field at the earth's surface due to the arriving waves. Now in the cases where σ is large compared with n, a simple modification of these formulæ gives the inclination of the major axis of the ellipse to the vertical (*i.e.*, β) in the expression:—

$$\tan \beta = \tfrac{1}{2}\sqrt{\frac{n}{\sigma}} \quad .. \quad .. \quad (2)$$

Referring to the experimental results given in Table I., it is seen that the measured values of β at Slough were 2°.0 and 2°.7 for waves whose frequencies were 400 000 and 670 000 cycles per second respectively. Substituting these in equation (2) above, the mean value of σ obtained is $0{\cdot}75 \times 10^8$. This figure is thus the measured value of the conductivity of the earth at Slough for wireless frequencies in absolute electrostatic units, and it corresponds to a resistivity of 13 300 ohms per cubic centimetre.

A knowledge of this effective conductivity of the earth is so important in the study of wireless wave propagation that the above experiments were repeated at several sites to ascertain the effect of soils of different materials and of varying moisture content, etc.

(*c*) *Extension of conductivity measurements to other parts of the country.*

For this purpose a portable Hertzian rod apparatus was constructed as shown in the photograph, Fig. 11. This apparatus is very similar in design to that installed at Slough as described in (3) above, but on a smaller scale. The straight wire forming the aerial was only 15 ft. long and the height of the supporting tripod only 5 ft. Owing to the reduction in size of the aerial system, the relative magnitude of the energy directly picked up by the tuning circuits, amplifiers, subsidiary apparatus and connecting leads was increased. By careful detailed attention to the screening of the apparatus, however, this difficulty was overcome and the apparatus was found to be quite as accurate as the larger instrument; the instrumental error was certainly less than 1°, and the mean of several readings as usually taken was probably correct to about 0°.5.

With this apparatus, experiments were carried out on some ten different sites on

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subsoils of as varied a nature as could be be found in the South of England, viz.: clay, sand, chalk, granite and serpentine rock. At several of the sites the measurements were repeated on a second occasion in an attempt to detect possible variations due to change in season or other causes. The results of these measurements carried out from May to September, 1924, are summarised in Tables IIA. and IIB.

These tables show that the effective conductivity of the ground at these various sites lies between 0.14×10^8 and 4.7×10^8, and that the state of the surface of the ground does not appreciably modify this value. Omitting in the first place the results obtained in Cornwall (Table IIB.), it is seen that the conductivities are of the same order as that at Slough, which gives an average representative value for the various sites selected well away from the coast. The actual value of σ at Slough given in Table IIA. is somewhat higher than that obtained in the earlier measurements given in Table I.

This discrepancy was discovered later to be due to the fact that the inclination of the

TABLE IIA.

RESULTS OF MEASUREMENTS ON FORWARD INCLINATION OF ELECTRIC FORCE (ANGLE β) AT VARIOUS PLACES WITH PORTABLE ROD RECEIVER.

Site.	Nature of sub-soil.	State of surface.	Date of Test.	Value of β measured on 2LO 365m.	5HW 450m.	5HW 750m.	Remarks.	Average Value † of σ obtained from β.
				Deg.	Deg.	Deg.		
Stoke Common, Bucks ..	Clay	Very wet	8.5.24	3.1	2.1	1.3		1.3×10^8
Walton Heath, Surrey ..	Sand	Moist	22.5.24	3.8	2.8	2.4		0.6×10^8
" " " ..	"	Very dry	8.7.24	3.3	2.8	2.1	After 4 weeks hot, dry weather	0.7×10^8
Chesham Bois, Bucks	Chalk	Wet	5.6.24	1.6	1.2	0.7	After 24 hours continuous rain.	4.7×10^8
" " "	"	Very dry	10.7.24	1.5	1.5	0.9	After 4 weeks hot, dry weather.	3.2×10^8
Marlborough Downs, Chisledon, Wilts.	"	" "	1.7.24	—	1.2	0.9	Measurements confirmed on longer waves 2 600 to 6 900m. β diminishing to 0.4 on latter wave	4.0×10^8
Slough, Bucks	Clay	Moist	3.7.24	2.4	1.8	1.3		1.5×10^8
" "	"	Dry	7.7.24	2.0	1.7	1.1		2.1×10^8
Princes Risborough, Bucks ..	Chalk	Dry	15.7.24	3.5	3.6	0.9	Taken on sloping ground.	1.6×10^8
" " " ..	"	Moist	5.8.24	1.7	15	1.4	On level site.	2.2×10^8
The Sands, Farnham, Surrey	Sand	Dry	17.7.24	2.1	2.1	1.4		1.5×10^8
Teddington, Middlesex ..	"	"	24.7.24	1.7	1.4	0.7		4.2×10^8

TABLE IIB.

RESULTS OF MEASUREMENTS ON FORWARD INCLINATION OF ELECTRIC FORCE (ANGLE β) AT VARIOUS PLACES WITH PORTABLE ROD RECEIVER.

Site.	Nature of sub-soil.	State of surface.	Date of test.	Value of β measured on 5WA 351m.	6BM 385m.	FFU & GLD 600m.	Remarks.	Average value † of σ obtained from β.
				Deg.	Deg.	Deg.		
The Lizard, Cornwall	Serpentine	Dry	9.9.24	1.9	1.5	—	On barren ground with outcropping rock, 1½ mile from coast.	2.4×10^8
" " "	"	"	10.9.24*	5.6	5.9	1.9	On rocky cliff path, ¼ mile from coast.	0.51×10^8
Land's End, Cornwall ..	Granite	"	11.9.24*	7.1	—	5.3	On rocky cliffs, 200 yards from coast.	0.17×10^8
" " " ..	"	"	" *	5.7	7.4	6.7	As above; 100 ft. nearer coast.	0.14×10^8

* NOTE.—The ground at the sites chosen at the Lizard and Land's End on 10th and 11th September was of very broken surface and varied nature. This, together with the proximity to the cliffs, probably accounts for the relatively large discrepancies in some of the results. In each case it was noticed that a slight shift in position of the apparatus resulted in a change in the values obtained, and in several positions the electric and magnetic fields were subject to appreciable sideways inclinations.

† For comparison purposes, it may be pointed out that the conductivity of sea water is of the order of 10^{10}

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electric field to the vertical varied in different parts of the field, as shown by the portable apparatus, and is evidently due to some local cause (such as the masses of trees in the vicinity, which has been previously shown to give rise to errors in apparent bearings of certain transmitting stations). This variation is not, however, large enough to affect any of the conclusions drawn from these conductivity measurements.

For comparison purposes it is interesting to note that the previously published values of the conductivities range from 10^9 to 10^6 or less for specimens of moist and dry earth, sand or clay ([5]). The more uniform values obtained in the present measurements are probably due to the fact that for wireless wave propagation the effective conductivity is not solely determined by the condition at the immediate surface. In England, even in the hottest summer weather, it is doubtful if the soil ever becomes thoroughly dry to a depth of more than a few feet, and it is the moist soil below which will in this case determine the forward inclination of the wave-front. Also, as Hack([6]) has previously shown, the presence of a layer of ground water at a depth of a fraction of a wave-length in a poorly-conducting soil will almost entirely annul the forward tilt of the wave-front which would otherwise be set up.

Referring now to the measurements made in Cornwall, as recorded at end of Table IIB., it is seen that in the first of these, at the Lizard, the conductivity obtained is similar to that at Slough. It is undoubtedly explained by the fact that the highly insulating serpentine rock sub-soil was mostly covered by a layer of one or two feet of surface soil with a moderate moisture content. Only at intervals over the surface was the rock projecting through the upper soil. The currents due to the arriving waves are unable to penetrate this comparatively highly conducting soil, which thus serves to "screen," as it were, the poorly conducting rock beneath. As the coast is approached, the depth of the soil layer decreases, and within a quarter of a mile of the edge of the cliffs the measurements show an appreciable drop in the conductivity values. For these latter measurements it was extremely difficult to find suitable sites, and the discrepancies occurring in the values of β measured on the different wave-lengths are considered to be due to the uneven rock surface, the consequently varying depth of surface soil, the stratification of the rocks, and the trapping of rain water in pools in the rock surface below the soil.

It is interesting to record here that during these measurements justification was obtained for the assumption that the inclination of the wave-front is related to the normal to the ground surface at the receiver, whereas the angles measured on the apparatus were related to the true vertical. At most places a suitable horizontal site could be obtained, but it was sometimes necessary to work on slightly sloping ground and make the necessary corrections for the direction and magnitude of the slope (usually less than 1°). On one occasion, however, a site was intentionally selected on the side of a hill sloping at about 16°, but after correcting for this, it was found that the values of β agreed with those measured on a level site in the same neighbourhood.

(*d*) *Conclusions.*

It is thus seen, from the experiments described in this section that the use of a Hertzian rod receiver for determining the direction of the electric field in the wave from a neighbouring transmitting station, affords a convenient means of measuring the earth's conductivity at wireless frequencies. Although at medium wave-lengths the angles to be measured are comparatively small, at shorter waves in the region of 300 to 600 metres the angle of departure of the electric field from the vertical is about 2° or 3°. Using the apparatus under these conditions values of the earth's conductivity have been obtained which are considered to be more accurate than those hitherto available for the study of the propagation of wireless waves over the earth's surface. The mean value of the conductivity as measured for typical soils and surface conditions encountered in England, is approximately 2×10^8 electrostatic units, corresponding to a resistivity of 5 000 ohms per cc.; whereas the resistivity of sea-water is from 25 to 100 ohms per cc., depending upon its exact composition.

As a practical conclusion, it is seen that in this country at any rate, the departure of the electric field from the vertical is so small that the loss of E.M.F. induced in a vertical aerial is inappreciable.

[5] Ref. 6, p. 623.

[6] J. ZENNECK. — Wireless Telegraphy, English Translation, 1915, pp. 260-2.

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IV. Wave-Front Measurements on Waves from Distant Transmitting Stations.

(a) *The Heaviside Layer theory of the propagation of waves.*

In the previous sections the manner in which wireless waves travel over the earth's surface at a distance of a few miles from the transmitter, has been demonstrated. It was shown that apart from the effects of local obstacles, the waves travel in horizontal straight lines, since a frame coil direction-finder indicates the true bearing of the transmitter: and that whatever shape or arrangement the transmitting coil or aerial may take, the magnetic field of the arriving wave is always horizontal and the electric field is tilted forward slightly in the direction of propagation by an amount depending upon the wave-length and the earth's conductivity. Now when the distance of transmission exceeds about fifty miles, the well known phenomena of fading of signals and variations in the apparent directions of arrival of the waves are experienced, and the above simple theory of wave propagation has to be augmented to explain these occurrences. To a limited extent both phenomena can be explained by the well known Heaviside layer theory with the modifications proposed by Dr. W. H. Eccles in 1912 and more recently elaborated by Sir Joseph Larmor, but adequate experimental evidence on the existence of the layer is still lacking.

On this theory, the direct wave travelling over the earth's surface is supposed to be accompanied at appreciable distances by a second wave or waves which were first projected from the transmitter into the upper portions of the earth's atmosphere, and then deflected sufficiently in the plane of propogation to allow them to reach the earth again at a distance. It will thus be evident that on this theory part of the energy at the receiver may be arriving at an appreciable angle of elevation to the horizontal, and the two or more waves will combine to give a resultant effect on the receiver. Owing to the varying absorption of the earth's atmosphere at different times of the day and night, however, the intensity of the downcoming wave may vary between wide limits, and its phase relative to that of the direct horizontal wave may also vary, due for example to changes in the height of the deflecting layer. Due to this phase variation, the forces of the downcoming wave may assist or oppose those of the direct wave, and this together with the variation in strength of the former may be the explanation of the variation in strength of the resultant fields commonly experienced as "fading." If also the plane of polarisation of the downcoming wave is rotated by any means, a possible explanation is obtained of the erratic manner in which the apparent bearings of distant transmitting stations vary as observed on direction-finders. This extension of the theory was first suggested by T. L. Eckersley in 1921.

(b) *Arrival of downcoming waves and boundary conditions at the earth's surface.*

Now, in considering the effects of a downcoming or incident wave at a receiver situated on the ground, *i.e.*, at the surface of separation between a conducting and a non-conducting medium, the effect of any reflected wave from the surface of the conductor must be taken into account. It is evident that if the earth were a perfect conductor, the reflected wave would be equal in amplitude to the incident wave, and a closer consideration of the case shows that the two waves would interfere at the surface in such a way as to tend to eliminate the horizontal component of the electric field and the vertical component of the magnetic field. Now, the experimental arrangements described in Section II. serve to determine the directions of the electric and magnetic forces which result from all waves arriving at the receiver. It is thus clear that if the earth is of sufficiently high conductivity such methods would be useless to detect downcoming waves at the earth's surface, since the resultant fields produced would be indistinguishable from those of an horizontally-propagated wave. By application of the electro-magnetic equations which apply in such a case, it can be shown that with the value of the earth's conductivity as determined above, the departure of the directions of the electric and magnetic forces from their normal directions for short-distance transmission is very small in the cases likely to be met with in practice, and that the angles concerned only become easily measurable for very short wave-lengths.

(c) *Experiments on more distant stations.*

In order to confirm the validity of these deductions a series of systematic measurements

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of the directions of the electric and magnetic fields in waves arriving from stations at appreciable distance, is being carried out at Slough. Table III. gives a summary of the results obtained over a period of seven months on the transmissions from various stations on medium wave-lengths.

apparatus for individual readings. It was frequently noticed during the observations on the frame coil apparatus, that the minimum obtained with the coil vertical was blurred, a common occurrence at night-time in wireless direction-finders. On all occasions, however, the minimum with coil in the horizontal position was sharp and well-

TABLE III.

SUMMARY OF RESULTS OF SIMULTANEOUS DIRECTIONAL MEASUREMENTS OF ELECTRIC AND MAGNETIC FIELDS AT SLOUGH.

Transmitting Station.	Distance.	Wave-length.	Frequency	Extreme Readings over a period of 7 months.				β calculated from $\sigma = 10^8$.
				α	β	γ	δ	
	Miles.	Km.	kcper sec.	Deg.	Deg.	Deg.	Deg.	Deg.
Nantes	302	9.0	33.3	+0.1 —1.3	0.0 —0.5	— 0.9 — 1.7	—0.3 —0.7	+0.5
Leafield	48.5	8.7	34.5	+1.1 —0.7	+0.5 —1.3	+12.0 —11.2	+1.0 —0.7	+0.5
Tours	165	6.8	44.2	0.0 —1.0	+1.1 0.0	+ 0.6 — 1.4	+0.3 —1.0	+0.5
Konigswusterhausen	608	5.3	56.6	0.0 —0.3	+1.5 0.0	+ 3.1 — 9.7	+1.0 —0.3	+0.6
Nauen	576	4.7	63.8	+0.5 —1.0	+1.5 +1.0	+ 9.8 — 5.7	+0.7 0.0	+0.6
Ongar (GLO) ..	36	4.4	68.2	+0.5 —0.5	+1.5 —0.7	+ 4.2 — 6.3	+0.8 —0.3	+0.8
,, (GLB) ..	36	3.8	79	+1.0 —1.0	+1.5 0.0	+ 2.3 — 2.5	+1.3 0.0	+0.8
Paris (FL)	221	2.6	116	0.0 —0.5	+1.0	+ 0.1	0.0 —0.1	+0.9

Many of the observations summarised above were purposely made on stations and at periods which experience had shown to be most likely to produce variations in γ (*i.e.*, directional errors or night effect) and it will be seen that variations as large as 23° were obtained. Yet the results show that on these occasions there were no corresponding variations in the values of α, β, and δ. In fact, throughout the whole series of observations and over the entire range of wave-lengths the values of α, β and δ do not depart from zero by more than 1.5°, a value which is inappreciably greater than the limit of accuracy of the defined, this indicating that the magnetic field was of elliptical form in a horizontal plane only.

Again referring to Table III., many of the stations are sufficiently distant for the phenomena of long-distance transmission to enter, and according to the Heaviside-layer theory most of the energy would be coming downwards from the layer. Yet in no case do the values of β differ by an appreciable amount from the theoretical values as recorded in the last column of the table; these values having been calculated from the conductivity of the ground at Slough as found experimentally.

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(*d*) *Conclusions.*

The above table of results is thus seen to support the deductions made in Section IV. (*b*) that waves arriving from appreciable distances and under conditions which may give rise to variations in apparent bearings as well as in signal intensity are not easily distinguishable from horizontally propagated waves from neighbouring stations by means of directional measurements of the electric and magnetic fields. As far as they have gone, therefore, the experiments cannot be considered as evidence for or against the existence of downcoming waves as required by the Heaviside-layer theory. A consideration of the theoretical analysis upon which these conclusions are based shows that in order to obtain positive results with this directional method of attacking the problem it will be necessary to either :—

(i.) Improve the accuracy of the apparatus and then repeat the experiments at Slough.

(ii.) Repeat the experiments with the existing apparatus but on the ground of lower conductivity, if it is practicable to find this.

(iii.) Repeat the experiments on the same site (at Slough) and with the same apparatus but on shorter wave-lengths.

All these possible lines of advance have their inherent difficulties, but they are all being pursued experimentally with the advantage of the more definite knowledge of the nature of the problem gained from the experiments described in this paper.

The R.I. Variable Condenser.

A RECENT product of Radio Instruments, Ltd., of 12, Hyde Street, New Oxford Street, W.C.1., is a well-made and efficient variable condenser. It is of the so-called "square law" variety, designed to give a straight line wave-length curve.

The vanes are of stout brass, and the end plates are of best quality ebonite, $\frac{1}{4}$ in. thick and $3\frac{1}{2}$ ins. in diameter. The bearings for the moving plates run in substantial bushes, and a special leaf spring of phosphor-bronze makes contact to the moving spindle and at the same time ensures an even pressure on it, so that the movement of the plates is very smooth. A single plate vernier is provided, and stops are provided for the moving plates in the shape of large ebonite washers between the fixed plates.

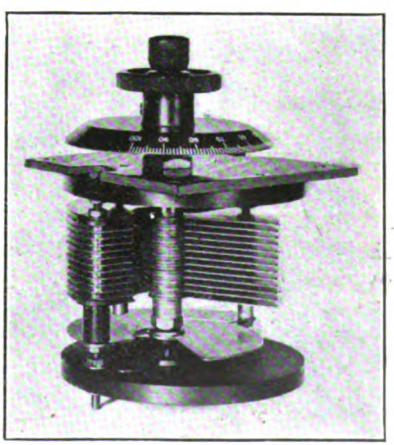
Attached to the upper end plate is a brass plate $3\frac{3}{4}$ ins. square by $\frac{1}{8}$ in. thick, which makes contact with the bush to the moving spindle and thence with the moving plates themselves. The effect of this is to diminish greatly hand-capacity effects when operating the knob and dial.

The condenser is arranged for the usual one-hole fixing, if desired, but owing to the fact that it is rather heavy, it is probably desirable to make use of the holes provided in the brass plate for fixing purposes. The knobs and dial are of ebonite, polished and engraved, and are fixed by means of grub screws. Altogether, the condenser is a mechanically sound job.

Electrically, it was found as good as it was mechanically. The condenser we tested was rated at .0005μF. The zero capacity was found to be remarkably low, being only 6.7$\mu\mu$F.

The capacity of the vernier was .000 03μF, and the total capacity was .000 59 μF, which is well over the rated capacity.

The condenser is made in two capacities : .0005μF and .00025μF, the prices being 24s. and 22s. 6d. respectively.



The R.I. Variable Condenser.

We understand that a new geared model is now being made, in which is incorporated a friction gear giving a reduction of 11 to 1. This should prove of great use for fine tuning purposes.

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The Design of Inductance Coils having a Rectangular Winding Section.

By S. Butterworth, M.Sc. **[R382**

THE mathematical formulæ for calculating the self-inductance of cylindrical coils of rectangular winding section are very complicated and, as they stand, are of little use to the designers of such coils. To help the computation, various writers have prepared curves by means of which it is possible to determine the inductance of a coil of known dimensions and of known total turns to an accuracy of about one per cent. For more accurate computation a set of tables prepared by Grover (*Scientific Paper, Bureau of Standards*, No. 455, 1922) may be employed.

1. Let the coil of which the inductance is required have a mean diameter d, a winding length b, and a winding depth c. Also let the whole number of turns in the coil be n. If we denote the ratios $\frac{c}{d}$ and $\frac{b}{c}$ by X and Y, then the formula for the inductance L may be written—

$$L = n^2 dQ \quad .. \quad .. \quad (1)$$

in which Q depends only on the shape of the coil; that is, it is a function of the two ratios X and Y. The tables of Grover and the curves of other writers enable the shape factor Q to be determined quickly.

Now formula (1) is very suitable for a coil already in existence, but what the designer usually knows initially is the inductance he desires, and he has to seek the number of turns and the diameter of coil that will give him this inductance. Usually the diameter of the wire and the spacing of the turns are fixed by considerations of current-carrying capacity and effective resistance, while the shape of the coil (fixing X and Y) depends upon the purpose of the coil.

It is preferable therefore to regard the inductance L, the turns (t)[1] per centimetre length, and the shape (X and Y) as the known quantities, while the absolute size of the coil is the quantity sought.

2. In order to use formula (1) when L, t, X and Y are given, we must remember that

$$n = t^2 cb = t^2 c^2 Y \quad (2)$$

while

$$d = \frac{c}{X} \quad (3)$$

so that

$$L = \frac{t^4 c^5 Y^2 Q}{X} \quad (4)$$

This formula involves a rather

An extremely interesting view of the valve-room at Daventry.

[1] Where the number of turns per cm. in each layer is not the same as the number of layers per centimetre, t is found as follows: let t_1 be the turns per cm. in each layer, and t_2 the layers per cm. Then:

$$t = \sqrt{t_1 t_2}$$

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long arithmetical computation to determine c. The formula may, however, be written—

$$c = \frac{AB}{C} \quad .. \quad .. \quad (5)$$

in which

$$A = L^{\frac{1}{2}} \quad .. \quad .. \quad .. \quad (6)$$

$$B = \frac{1}{t^{\frac{1}{2}}} \quad .. \quad .. \quad .. \quad (7)$$

$$C = \left(\frac{Y^2 Q}{X}\right)^{\frac{1}{2}} \quad .. \quad .. \quad (8)$$

A depends only on the inductance, B on the turns per centimetre, and C is a shape factor depending on the two ratios X and Y. Further, by the introduction of suitable constants, we can in nearly all cases confine the values of A, B and C to numbers lying between one and ten, so that when tables for A, B and C have been computed the operation for determining the size c is reduced to a single slide-rule setting, and no mental effort is necessary in fixing the decimal point.

Again, since formula (5) may be written—

$$A = \frac{cC}{B} \quad .. \quad .. \quad .. \quad (9)$$

and L may be read off immediately from the table connecting L with A, the new computation formula can be used as readily as formula (1) for the determination of the inductance of coils of known dimensions.

3. The tables given below have been computed with the help of Grover's published tables referred to above.

TABLE I.

Inductance Factor A.

Milli-henries.	A.	Milli-henries.	A.	Milli-henries.	A.	Henries.	A.	Henries.	A.
0.1	1.149	1	1.821	10	2.885	0.1	4.573	1	7.248
0.2	1.319	2	2.091	20	3.315	0.2	5.213	2	8.326
0.3	1.431	3	2.268	30	3.594	0.3	5.697	3	9.029
0.4	1.516	4	2.402	40	3.807	0.4	6.028	4	9.554
0.5	1.585	5	2.512	50	3.981	0.5	6.310	5	10 000
0.6	1.644	6	2.605	60	4.129	0.6	6.544	6	10.372
0.7	1.695	7	2.687	70	4.258	0.7	6.749	7	10.697
0.8	1.741	8	2.759	80	4.373	0.8	6.931	8	10.985
0.9	1.783	9	2.825	90	4.478	0.9	7.097	9	11.247
1.0	1.821	10	2.885	100	4.573	1.0	7.248	10	11.487

NOTE.—If L is less than 100 microhenries, calculate for 100 000 L and then divide the size by 10; if L is greater than 10 henries, calculate for $\frac{L}{100\,000}$ and then multiply the size by 10.

TABLE II.

Turns Factor B.

t = turns per centimetre length, and is the reciprocal of the mean distance apart of neighbouring turns.[2]

t	B	t	B	t	B	t	B
1	10.000	9	1.724	17	1.037	25	0.761
2	5.744	10	1.585	18	0.990	26	0.736
3	4.152	11	1.469	19	0.948	27	0.716
4	3.298	12	1.370	20	0.910	28	0.695
5	2.760	13	1.285	21	0.875	29	0.676
6	2.385	14	1.211	22	0.843	30	0.658
7	2.108	15	1.146	23	0.814	31	0.641
8	1.895	16	1.088	24	0.787	32	0.625

[2] See previous note.

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TABLE III.

Shape Factor C.

Flat coils, that is coils whose winding depth c is greater than the winding length b. (See Fig. 1.)

Formula for length of side c in centimetres is :—

$$c=\frac{AB}{C} \qquad X=\frac{c}{d} \qquad Y=\frac{b}{c}$$

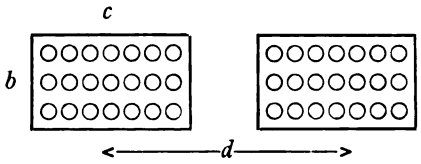

Fig. 1.

X	0.025	0.05	0.1	0.2	0.4	0.6	0.8	1.0
Y								
0.1	1.864	1.569	1.311	1.086	0.887	0.781	0.711	0.662
0.2	2.450	2.061	1.722	1.423	1.158	1.017	0.925	0.860
0.3	2.870	2.413	2.014	1.662	1.350	1.182	1.073	0.996
0.4	3.209	2.696	2.248	1.853	1.500	1.312	1.189	1.102
0.5	3.498	2.937	2 446	2.013	1.626	1.419	1.283	1.188
0.6	3.751	3.147	2.619	2.152	1.735	1.511	1.365	1.262
0.7	3.978	3.335	2.773	2.270	1.830	1.592	1.435	1.326
0.8	4.184	3.506	2.912	2.387	1.911	1.663	1.498	1.383
0.9	4.374	3.663	3.040	2.489	1.993	1.728	1.554	1.434

TABLE IV.

Shape Factor C.

Solenoidal coils, that is coils whose winding length b is greater than the winding depth c. (See Fig. 2.)

Formula for length of side b in centimetres is :—

$$b=\frac{AB}{C} \qquad X=\frac{c}{d} \qquad Y=\frac{b}{c}$$

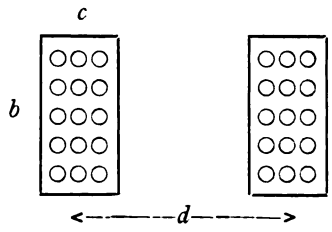

Fig. 2.

X.	0.025	0.05	0.1	0.2	0.4	0.6	0.8	1.0
1/Y								
0.1	1.020	0.829	0.659	0.510	0.386	0.324	0.286	0.261
0.2	1.622	1.335	1.081	0.854	0.656	0.554	0.491	0.449
0.3	2.114	1.815	1.430	1.142	0.886	0 753	0.669	0.613
0.4	2.546	2.117	1.736	1.397	1.092	0.932	0.830	0.761
0.5	2.937	2.446	2.014	1.627	1.281	1.096	0.978	0.898
0.6	3.298	2.751	2.270	1.841	1.455	1.250	1.118	1.027
0.7	3.636	3.037	2.510	2.041	1.619	1.394	1.249	1.149
0.8	3.956	3.307	2.737	2.230	1.775	1.531	1.373	1.264
0.9	4.260	3.563	2.952	2.410	1.923	1.662	1.492	1.374
1.0	4.550	3.809	3.159	2.582	2.064	1.787	1.605	1.480

NOTE.—Whether we are dealing with flat or solenoidal coils it is the *greater* of the two sides b, c, which is determined by the formula.

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4. Examples.

(1) Let a coil of 100 millihenries be required wound with No. 22 D.C.C. wire and having a square winding section whose side is 0.4 times the mean diameter of the coil. From Table I. the inductance factor A is 4.573. The diameter of bare No. 22 wire is 0.71 mm., so that, allowing 0.29 mm. for insulation, the overall diameter of the wire is 1 mm. which gives 10 turns per centimetre if the coil is closely wound. Hence from Table II. the turns factor B is 1.585. From Table IV. the shape factor C is 2.064. Therefore the side of the winding section must be

$$\frac{4.573 \times 1.585}{2.064} = 3.512 \text{ cms.}$$

The mean diameter of the coil must be

$$\frac{3.512}{0.4} = 8.78 \text{ cms.}$$

For the dimensions of the coil-former we therefore have

Internal diameter $8.78 - 3.51 = 5.27$ cms.
External diameter $8.78 + 3.51 = 12.29$ cms.

The area of the winding section is 15.67 sq. cms., and as there are 100 turns per square centimetre, the number of turns required is 1 567. In practice one would wind, say, 1 600 turns and adjust experimentally.

(2) Let a flat coil of 1 henry be required having the following dimensions:—

$b = 2.5$ cms.; $c = 5$ cms.; $d = 10$ cms.

The number of turns is to be found.

From Table I., $A = 7.248$. Since $X = 0.5 = Y$, we have from Table III. $C = 1.52$, and since c is 5 cms., $B = \frac{5 \times 1.52}{7.25} = 1.048$. Therefore, from Table II. the turns per centimetre are 16.8, and the total turns $(16.8)^2 \times 5 \times 2.5 = 3\,530$.

5. Most Economical Shape of Coil.

It is clear from formula (1) that we may wind a coil of considerable inductance with a very small weight of copper by using very thin wire with the turns closely packed, but such a coil would possess a large direct current resistance, and with alternating currents, the close packing would bring about considerable eddy current losses in the copper. We will suppose, therefore, that the diameter of the wire and the spacing of the turns is fixed by considerations such as given above, and our problem is to determine the shape of coil which will give the requisite inductance with the smallest length of wire. This coil would clearly have the smallest direct current resistance and be the most economical in copper.

The diameter of the wire being fixed, the length of wire is proportional to the volume of copper in the coil; and, the spacing of the turns being fixed, the copper volume is proportional to the volume of the winding space. This volume is given by—

$$V = \pi bcd = \frac{\pi c^3 Y}{X} = \frac{\pi b^3}{Y^2 X} \quad .. \quad (10)$$

Using the formulæ of Tables III. or IV. to express c or b in terms of A, B and C, we have, for flat coils—

$$V = \frac{\pi (AB)^3 Y}{C^3 X} \quad .. \quad .. \quad (11)$$

and for solenoidal coils—

$$V = \frac{\pi (AB)^3}{C^3 Y^2 X} \quad .. \quad .. \quad (12)$$

Now, for a given inductance A is fixed, and for a given diameter of wire and spacing B is fixed, so that to determine the best shape of coil we must calculate $\frac{\pi Y}{C^3 X}$ for various shapes of flat coils, and $\frac{\pi}{C^3 Y^2 X}$ for various shapes of solenoidal coils, and find for what shape of coil this quantity is the least.

The results for three shapes of winding are given in Table V.

The first shape is that for a flat coil the winding depth of which is twice its winding length ($Y = 0.5$); the form ranges from a hoop-like coil whose mean diameter is 40 times the winding depth to a coil wound full from the centre as we proceed from left to right across the table. The most economical coil of this type is one whose winding depth is one-half the mean diameter or one-third the overall diameter. The volume of the winding space for this coil is $= 0.91(AB)^3$.

For the second shape (a coil of square winding section) the best case is when the side of the winding section is one-third the mean or one-quarter the overall diameter, and then $V = 0.88(AB)^3$.

The third shape, a solenoidal coil of which the winding length is twice its winding depth, should be proportioned so as to make the winding depth one-quarter the mean diameter or one-fifth the overall diameter; and then $V = 0.91(AB)^3$. Of the three shapes the square-sectioned coil is the most economical, but it is clear from the table that we have considerable latitude without undue waste of copper.

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TABLE V.

VALUES OF G.

Volume of winding space $= G(AB)^3$.

X	0.025	0.05	0.1	0.2	0.4	0.6	0.8	1.0
Y								
0.5	1.47	1.24	1.07	0.96	0.91	0.91	0.93	0.94
1.0	1.33	1.14	1.00	0.91	0.89	0.92	0.95	0.97
2.0	1.24	1.07	0.96	0.91	0.93	0.99	1.04	1.08

TABLE VI. (*see p.* 755).

VALUES OF G'.

Overall volume $= G'(AB)^3$.

X	0.025	0.05	0.1	0.2	0.4	0.6	0.8	1.0
Y								
0.5	15.4	6.85	3.25	1.74	1.12	0.97	0.95	0.94
1.0	13.9	6.30	3.03	1.65	1.10	0.98	0.97	0.97
2.0	13.0	5.90	2.91	1.65	1.14	1.06	1.06	1.08

The most compact coil is clearly turning out to be one which is wound full from the centre and of the "flat" type. The values of G' for fully wound coils ($X = 1$) are—

Y	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
G'	1.08	0.99	0.95	0.94	0.94	0.94	0.94	0.95	0.96	0.97

TABLE VII. (*see p.* 755).

COEFFICIENTS OF COUPLING BETWEEN COAXIAL FLAT COILS IN END CONTACT.

X	0.025	0.05	0.1	0.2	0.4	0.6	0.8	1.0
Y								
0.1	0.97	0.96	0.95	0.93	0.90	0.87	0.86	0.85
0.2	0.93	0.92	0.89	0.87	0.82	0.79	0.75	0.73
0.3	0.91	0.89	0.86	0.82	0.75	0.71	0.67	0.65
0.4	0.88	0.86	0.83	0.77	0.68	0.64	0.59	0.56
0.5	0.86	0.83	0.79	0.72	0.65	0.58	0.53	0.50

NOTE.—$X = \frac{c}{d}$ $Y = \frac{b}{c}$ and they refer to *one coil.*

TABLE VIII.

VALUES OF H IN FORMULA (16).

X	0.025	0.05	0.1	0.2	0.4	0.6	0.8	1.0
Y								
0.1	1.98	1.66	1.44	1.23	1.21	1.20	1.19	1.18
0.2	1.79	1.51	1.31	1.18	1.14	1.15	1.17	1.20
0.3	1.74	1.44	1.28	1.13	1.13	1.16	1.22	1.24
0.4	1.64	1.41	1.23	1.16	1.17	1.22	1.28	1.33
0.5	1.60	1.38	1.24	1.17	1.18	1.27	1.36	1.43

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6. Most Compact Coil.

Sometimes economy in space is more desirable than economy in copper. In this case, we require to find the coil that will have the minimum overall volume when wound to have a given inductance with wire of given diameter and given spacing of turns. The overall volume is—

$$V' = \frac{\pi b(c+d)^2}{4} = \frac{V(1+X)^2}{4X}$$

Thus the condition for minimum overall volume is found by multiplying all the G factors of Table V. by $\frac{(1+X)^2}{4X}$ and finding which of these products is the least.

The results are given in Table VI. (p. 754).

There is therefore practically nothing to choose between fully wound coils whose length lies between 0.2 and 0.4 times the overall diameter.

7. Mutual Inductance Between Cylindrical Coils in End Contact.

The tables given above for the calculation of self-inductance may readily be adapted for the design of mutual inductances. Let the two coils be of similar shape and size and let them be coaxial and in end contact.

Let L_1, L_2 be the self-inductances of the two coils and M the mutual inductance. Since the self-inductances are proportional to the square of the turns and the mutual inductance to the product of the turns in either coil, the coefficient of coupling (k) which is defined by—

$$k^2 = \frac{M^2}{L_1 L_2} \quad (13)$$

is independent of the turns and may therefore be calculated for equal coils. In this case, if L' is the total self-inductance of the two coils when in series and helping, we have—

$$L' = 2(L + M) \quad (14)$$

and therefore

$$k = M/L = \frac{L'}{2L} - 1 = \frac{2Q'}{Q} - 1 \quad .. \quad (15)$$

when the values of L' and L as given by formula (1) are used. In this formula, Q' is the shape factor for the two coils in series and Q the shape factor for either coil separately. From formula (15) Table VII. of coefficients of coupling has been calculated (see p. 754).

To determine the size of coils required to produce a given mutual inductance, when the coils are to be of equal turns, divide the mutual inductance by k, thus obtaining the self-inductance of either coil; and then calculate the size as in sections 3 and 4. For coils of unequal turns divide M also by the ratio of secondary to primary turns to obtain the primary self-inductance.

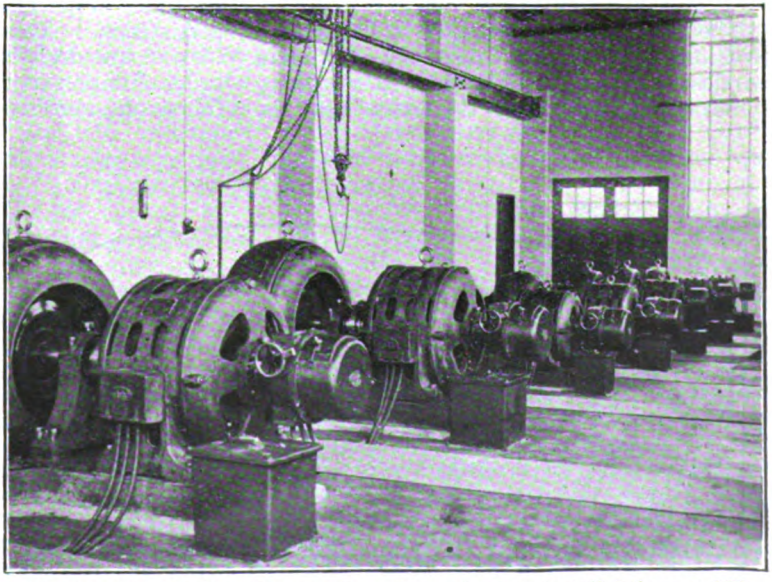
As in the case of self-inductance, we may determine the most economical pair of coils to give a fixed mutual inductance. If V is the volume of the winding space in either coil—

$$V = H(AB)^3 \quad .. \quad .. \quad (16)$$

where $H\left(\equiv \frac{G}{k^3}\right)$ is given by Table VIII.

The most economical pair of coils is that for which $X = 0.3 = Y$.

The Author is indebted to the Admiralty for permission to publish the tables given in this article.



A view of the Machine Room at Daventry, where are installed three 70 kW motor alternators (two of them are visible in the foreground above); two 25 kW motor alternators; and three 10 kW motor generators.

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Distortion in Wireless Telephony, and Related Applications of the Cathode Ray Oscillograph.

By E. K. Sandeman and N. Kipping. **[R135-R388**

Summary.

THIS article is divided into two main parts. The first part discusses generally the causes of distortion in wireless telephony; after various types of distortion are defined the chief sources of each type are enumerated and discussed. In the second part, the application of the cathode ray oscillograph to the study of various forms of distortion and related work is dealt with; photographs are used to show the kind of results obtained, and their interpretation is explained.

Appendices are added to deal with (I.) A mathematical explanation of the process of modulation and detection; and (II.) A description of a linear time base. There is also a note describing the cathode ray oscillograph, which is appended to the end of this part. The article concludes with a bibliography.

Introductory.

The purpose of this article is two-fold—to discuss generally the causes of distortion in wireless telephony, and to show in what way some of the effects of distortion may be studied with the Cathode Ray Oscillograph. It is not to be understood that this type of oscillograph is considered to be the only, or necessarily the best means of making such a study in all cases, but it is in itself of very considerable interest, and is for that reason being dealt with. Its special interest lies, perhaps, in its ability to present visual results, as will be seen by reference to the note on page 765, in which the oscillograph is briefly described for the benefit of those who are not already familiar with its function.

DISTORTION IN WIRELESS TELEPHONY.

Distortion in the reproduction of speech or of music is primarily of two kinds, which we shall term "frequency distortion" and "asymmetric distortion" respectively. Of other kinds of distortion of less frequent occurrence or of a less troublesome nature, the most important we shall term "sound persistence." These various kinds of distortion are dealt with in the article not in order of importance, but as they conveniently follow one another by their nature.

Frequency distortion is the name which has been given to the type of distortion in which different frequencies are produced with unequal efficiency. That which has been termed asymmetric distortion occurs when non-linearity of characteristic exists, and results in the production of frequencies which were not present in the original sound wave.

Sound persistence is the effect produced

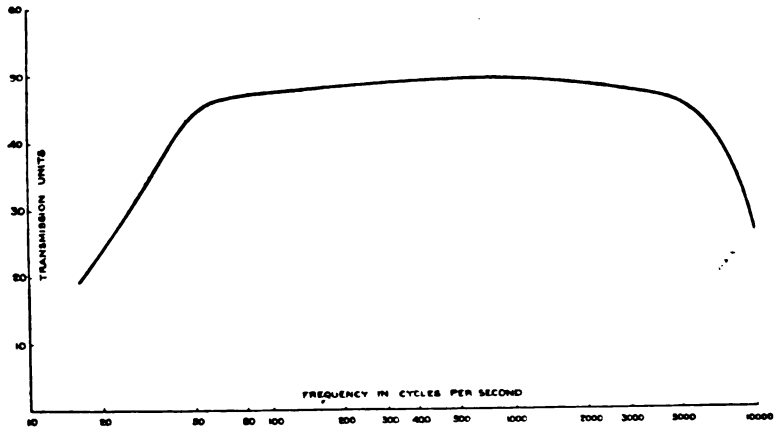

Fig. 1. *Characteristic of amplifier employing tuned transformers.*

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when sounds tend to persist for a longer period in reproduction than when first produced.

Frequency Distortion.

General.—One of the most fruitful sources of this type of distortion is audio-frequency resonance of any kind, whether electrical or mechanical, resulting in the production of some frequencies more efficiently than others. Audio-frequency resonance may occur in the microphone or sound collecting device, or in the loud-speaker or sound reproducing device, as well as in the audio-frequency amplifiers.

Radio frequency resonance—that is the effect of tuning circuits on audio-frequency reproduction—should also be considered under the heading of frequency distortion.

Audio-Frequency Case.—In low frequency amplifiers, distortion is unavoidably caused by the shunt capacity effects introduced by the wiring, and is also aggravated in some cases by the necessary shielding. This effect, which applies both to resistance coupled and to transformer coupled amplifiers, results in a falling off in the amplification at high frequencies (above 5 000 cycles).

In resistance coupled amplifiers, distortion may be caused by the use of condensers for coupling purposes which are too small, with the result that amplification falls off at the low frequencies; to obtain the best results, condensers not less than 1μF should be employed. The value of the low frequencies in the reproduction of speech or music for affording pleasure does not appear to be generally appreciated, although the taste of the public in choosing reproducing apparatus having a low tone is fairly marked. This would seem to be not because the absence of high frequencies is desirable but because hitherto the only apparatus capable of adequately reproducing the low frequencies has unfortunately done so at the expense of the high frequencies.

With transformer coupled amplifiers, as is well known, there may be considerable distortion due to the difficulty of designing and manufacturing a transformer which has equal efficiency at all frequencies in the music range. The science of transformer design is in itself a very large subject, but briefly the chief difficulty experienced is that of securing an adequately large inductance without the attendant self-capacity which a large winding always involves.

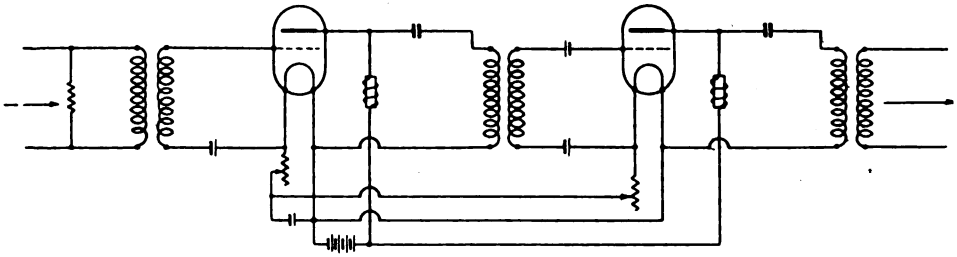

Fig. 1a. *Circuit of amplifier employing tuned transformers.*

For general purposes the music range is usually considered to extend from 30 to 10 000 cycles. Experience has shown however, that from the point of view of æsthetic pleasure, frequencies above 6 000 cycles are of sufficiently small importance to be negligible, and economic considerations usually restrict the reproduced range accordingly.

By means of a very simple system of equalisation, however, it is now possible to build transformer coupled amplifiers whose performance is on the whole preferable to that of resistance coupled amplifiers having regard to the greater efficiency obtainable. A typical curve which has been obtained with the use of a system of equalisation is shown in Fig. 1. The method of equalisation employed to obtain this characteristic is illustrated in Fig. 1a which is extracted from a paper by R.W. King in the *Bell System Technical Journal* for October, 1923. It will be seen that the system involves the use of tuned transformers.

A word of explanation should perhaps be inserted here regarding the "Transmission Unit," in terms of which the above amplification curve is plotted. In view of the fact that the input and output impedances

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of an amplifier may be different, an expression of actual voltage amplification is misleading and the only true expression of amplification is in terms of power ratio. The Transmission Unit is defined so that two powers (P_s P_r)

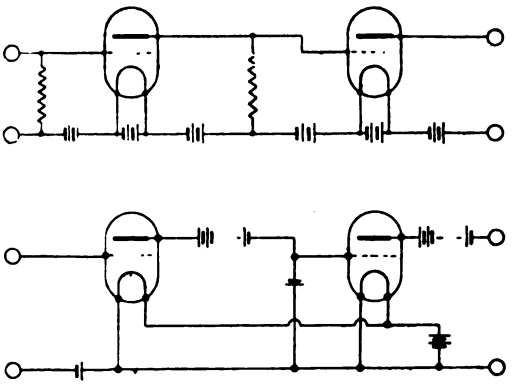

Fig. 2. *Battery coupled amplifiers.*

differ by one Transmission Unit if they are in the ratio $10^{0.1}$: 1 so that the gain of an amplifier expressed in T.U.

$$= 10\ Log_{10} \frac{P_s}{P_r}$$

where P_s = the power delivered by the amplifier.

Pr = the power received.

The table gives equivalent power ratio corresponding to different values of amplification expressed in Transmission Units.

T.U.	Power Ratio.	T.U.	Power Ratio.
1	1.26	9	7.94
2	1.59	10	10.0
3	2.00	15	31.6
4	2.51	20	10^2
5	3.16	30	10^3
6	3.96	40	10^4
7	5.01	50	10^5
8	6.31	100	10^{10}

The above table enables any number of T.U. to be expressed directly as a power ratio. For instance, 45 T.U. = 40 + 5 T.U. =10,000 × 3.16 = 31 600 Power Ratio.

Perhaps mention should not be omitted of the battery coupled amplifier, which represents the acme of distortionless amplification, and for which two circuits are represented in Fig. 2. Such an amplifier is capable of reproducing uniformly all frequencies from very nearly zero frequency up to frequencies above the limit of audibility. It represents practically the earliest type of amplifier and from a performance point of view is undoubtedly the best; from an economic standpoint however it is rather expensive.

Radio Frequency Case.—While in the radio frequency case the effect of shunt capacities is more serious than in the audio frequency case, and while also high frequency transformers transmit different radio frequencies with unequal efficiency, the effects on the audio frequency wave after detection may generally be made so small as to be negligible. The way in which these effects may cause distortion in the audio frequency wave is explained more fully in the case of radio frequency resonance, which we will not consider.

The case of radio frequency resonance, that is the effect of the tuning circuits on the audio frequency reproduction, has been mentioned by many authors, but does not appear to have been investigated very completely in most cases.

The process of modulation of a carrier wave by a series of voice frequency waves gives rise in practice to the production of a large number of audio frequency combination tones, as well as a corresponding number of radio combination frequencies. Also, all the original impressed frequencies and their second harmonics are present. The audio frequency components are suppressed by the tuning of the antenna system, and its natural inefficiency of radiation at such low frequencies. The desired radio frequencies are selected from the unwanted radio frequencies by means of the aerial tuning system and so are radiated. Thus, as indicated in Appendix 1, each voice frequency wave produces two radio frequencies, one greater and one less than the carrier frequency, and which differ from the carrier frequency by the amount of the original audio frequency.

On detection, the two frequencies in the two side bands (or one frequency if only one side band is transmitted) combine with the carrier frequency to form the original

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voice frequency. Actually, the carrier frequency may be either transmitted with the other radio frequencies formed, or may be supplied by the local receiving station. And provided the relative amplitudes of the side band frequencies after reception are the same as the relative amplitudes of the initial audio frequencies, the audio frequencies on detection will bear the same amplitude relations to one another as they did before modulation.

In practice we know that this ideal condition is not obtained owing to distortion in the tuning circuits both in the transmitter and in the receiving set. Fig. 3 shows three curves which were obtained by one of the authors in conjunction with Mr. E. Swensen. Curve *A*, shows the complete frequency distortion contained in the modulator, sub-modulator and radiation circuits of the Birmingham Broadcasting Station. This curve of course, includes the distortion in the input transformer to the submodulator valve, and in the coupling to the modulator, but it suffices to show how small the tuning distortion actually is. These curves were obtained by receiving on a calibrated wireless receiving set and measuring the received signal strengths at each frequency. Part of the calibration of this set is shown on curve *B* which shows the distortion due to the (single) tuning circuit of this set. The tuning circuit on which this measurement was obtained consisting of a number 50 Igranic coil tuned to 708 000 cycles (425 metres) with a 0.0005 variable condenser. The distortion is shown as the amplitude of the reproduced voltages at each frequency relative to unity reproduction at 500 cycles. This method of portrayal has the advantage that distortions in successive pieces of apparatus in tandem may be obtained by multiplying corresponding ordinates. For instance curve *C*, in which every ordinate is the square of the corresponding ordinate in curve *B*, shows the distortion which would be introduced by two tuning circuits in tandem.

Reaction.—Reaction at radio frequencies, if not carried to excess, merely serves to modify the impedance of the receiving circuit.

This effect is represented approximately for the case of series resonance in Fig. 4, which is intended to indicate that for equal positive reactance at all frequencies (represented by the vectors (*a*) while the admittance is always increased by a vector of constant relative size, the relative phase in which this vector is added changes as the angle of the admittance changes.

The large vectors Y represent the admittance of the receiving circuit without reaction. The small vectors a, b, c and $d=KY$ represent the increase in admittance due to reaction, where K is a constant depending on the value of the reacting E.M.F. If we imagine the receiving circuit to be tuned to the carrier wave-length of some transmitting station and the reaction adjusted so that the phase of the reacting E.M.F. produces a maximum increase in admittance as indicated by the vector $a=KY$, then the reaction will increase the admittance to the upper and lower side bands as indicated by $a=KY_L$ and $a=YC$ respectively.

The net result is that the fineness of tuning is increased. For clearness we have only shown a very small degree of reaction, but

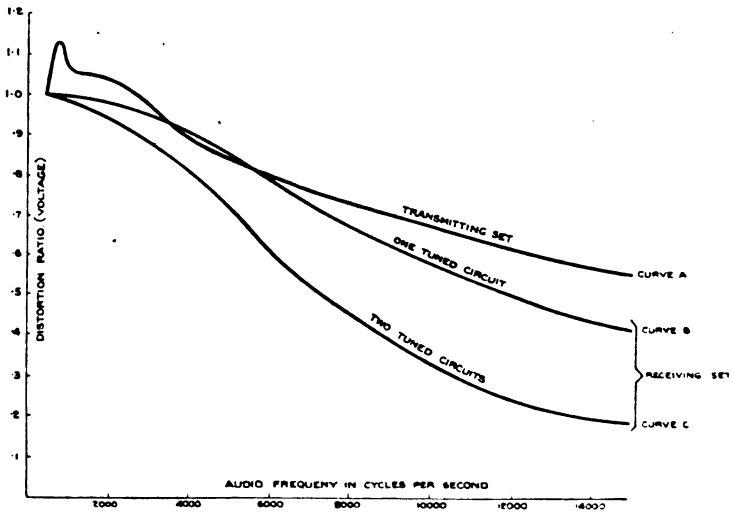

Fig. 3. *Diagram indicating distortion in transmitting and receiving set due to tuning circuits.*

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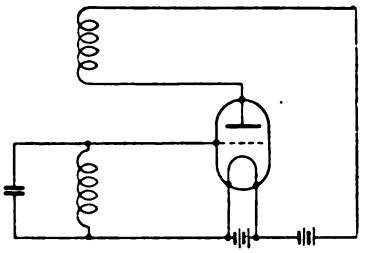
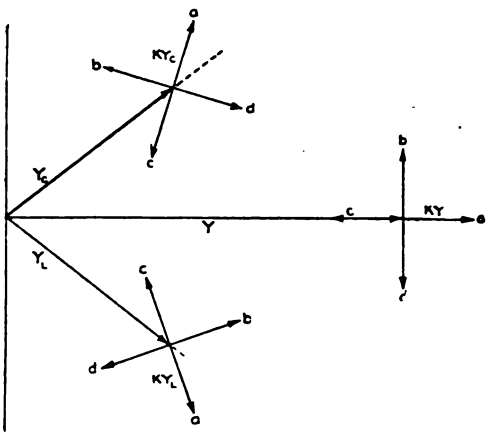
in the limits of reaction this effect is enormously increased. The vectors marked (*c*) represent the case of pure negative reaction, while (*b*) and (*d*) represent the case of 90° lag or lead in the reacting E.M.F. compared with the signal E.M.F. The effect of these is respectively to reduce the capacities and inductive reactance of the circuit.

The reacting forces considered in Fig. 4



SIMPLE REACTION CIRCUIT



Y · ADMITTANCE FOR RESONANCE WAVE LENGTH
Y_C " WAVE LENGTHS ABOVE RESONANCE
Y_L " " " BELOW
KY ADDED EFFECTIVE ADMITTANCE DUE TO REACTANCE

VECTOR DIAGRAM OF ADMITTANCES

Fig. 4.

may not only include those intentionally introduced by magnetic coupling, they may also arise from, for instance, valve capacities, leakage and unbalanced wiring capacities, in addition to accidental coil couplings and capacities between coils. In this case, of course, due allowance must be made for any phase shifts which occur owing to the nature of the reaction path.

It is fairly safe to say that whenever audio-frequency reaction occurs, frequency distortion will also result, although this does not necessarily follow. If the reaction were such that the feed back paths had an equal attenuation (or coupling) at all frequencies and such that the phase retardation was independent of frequency, then frequency distortion would not occur; but even so, such reaction would still be highly undesirable, as is explained later. Unintentional audio-frequency reaction may be due to exactly similar causes to those in the radio-frequency case, although not in the same degree. It is usually not until amplifications of the order of one hundred million times (energy ratio) are reached that any serious difficulties are met with under this heading. Provided an amplifier is well shielded, possesses balanced inputs and outputs, and has small capacities between the separate windings of its input and output transformers, little difficulty is likely to be experienced.

Sound Persistence.

Audio-frequency reaction always tends to prolong any oscillation which is applied to the input of the amplifier. The result, to the ear, is a peculiar ringing quality, similar to that obtained from speech or music in a particularly reverberant room. The mechanism of this case is analogous to that of the high frequency case, although the actual effect is, of course, different.

Another cause of sound persistence which is frequently extremely troublesome is due to the acoustic properties of the place where the sound is being initially produced, and it follows, of the place where it is being reproduced after transmission and reception. If insufficient damping is provided in these places, the reflection of the sound from the walls, floor and ceiling of the rooms causes continued echoes which tend to prolong the sound unduly. Reverberation is the term given to the result of continued reflections, which result in a number of sound images being impressed on the microphone or on the ear. Reverberation may be reduced to any required degree by suitably covering the walls of the room with some sound-absorbing textile material, such as felt.

Asymmetric Distortion.

Asymmetric distortion is probably the most objectionable type of distortion with which we have to cope, and it is the least excusable type, since wherever it occurs

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poor design or careless handling are indicated. Its cause is non-linearity in the output versus input characteristic of any

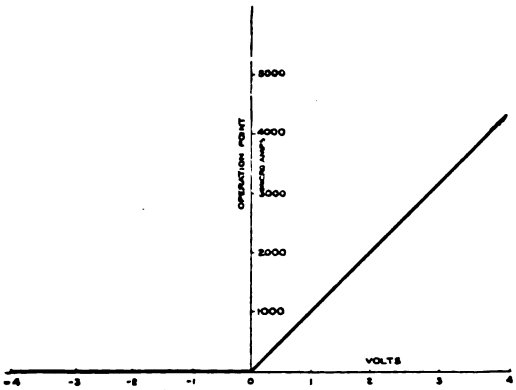

Fig. 5. (a.) *Ideal Rectifier.*

piece of apparatus in the transmission system. This departure from linearity may occur in vacuum tubes due to operation beyond the straight part of the plate current grid-voltage characteristic in transformers due to operation over too great a part of the **B**—**H** curve (as a result generally of too small a core being used, or of the use of core material for which the lower knee in the **B**—**H** curve occurs at too low a value of **B**) and in microphones or loud-speakers due to the elastic controlling forces not having a linear displacement-control law.

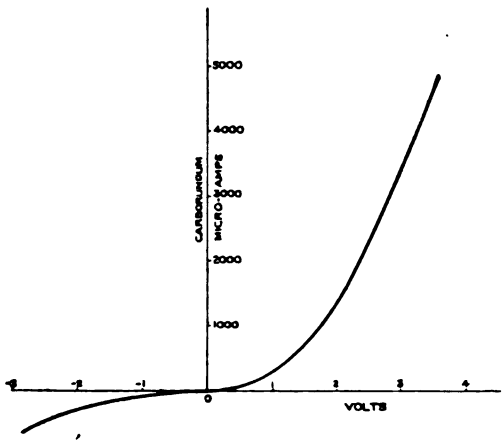

Fig. 5. (b.) *Carborundum Crystal Rectifier.*

It is the limits referred to above which in general define "overloading," considered in the telephone sense, and not questions of heat dissipation. As soon as the amplitude of energy pulses in any piece of apparatus exceeds the limits for which linearity of characteristic holds, then that piece of apparatus is said to be overloaded. Overloading of a valve clearly occurs as soon as the amplitude of the voltage pulses applied to the grid pass beyond the zero of grid-potential, at which point grid-current begins to flow, and the instantaneous impedance of the valve becomes a function of voltage amplitude.

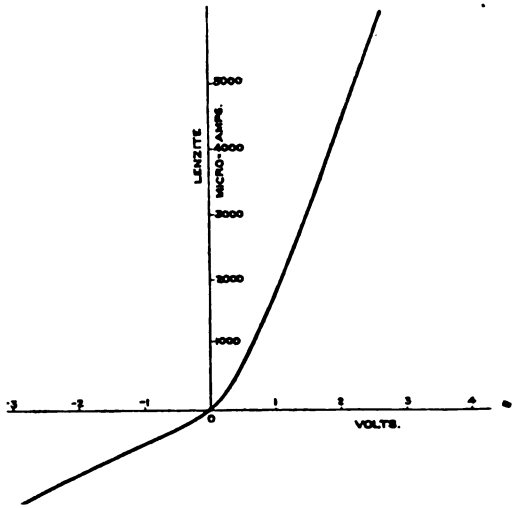

Fig. 5. (c.) *Lenzite Crystal Rectifier.*

Modulation and Detection—If we are to hold rigidly to our definitions of asymmetric distortion we must include under that heading the distortion introduced on normal modulation and detection. Provided we have chosen a proper system of modulation, even if the carrier wave is modulated to a depth of 100 per cent., detection on a straight line rectifier should reproduce the original wave form exactly. In practice it is economically impossible to avoid the peaks of the audio-frequency voltages from rising above the value required for 100 per cent. modulation; this effect (which is termed "over-modulation" and which may really be regarded as an overloading of the modulator) can however, be kept so small that the resulting harmonics are within the limits of tolerance of the ear. If we work with a mean modulation of 10 per cent. then we assume that the peak voltages are not greater than 10 times the mean voltage; this is practically true for normal continued speech but not so for music.

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Even if no over-modulation occurs, the use of rectifiers of parabolic output versus input characteristic introduces a number of additional frequencies not present in the original audio-frequency wave, which are sometimes spoken of as frequencies of asymmentry or combination tones.

In Fig. 5 are shown rectification characteristics of two crystal combinations compared with the ideal rectifier characteristic. The curves for these crystals are taken from Morecroft's "Radio Communication." The lenzite crystal rectifier gives a characteristic which approximates very closely to the ideal on the positive side, while the carborundum combination gives a curve more nearly a parabola. It may here be pointed out that a crystal detector when receiving strong signals tends to approximate to a straight line rectifier; this is fairly evident from the curves in Fig. 5.

In detection by valves, one of two methods is employed. In the first, the

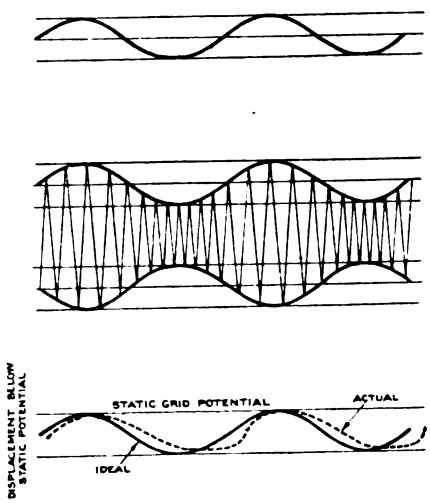

Fig. 6.

modulated wave is rectified by apparatus having approximately a parabolic form of characteristic, and the percentage of combination frequencies produced is proportional to the depth of modulation; that is to say, to the ratio of the side-band amplitude to the carrier amplitude.

The second ordinary method of demodulation—known as grid detection—is of a complex nature. Although it employs apparatus having a linear characteristic, and is not necessarily to be considered as rectification, a certain amount of asymmetry usually occurs. Ideally, grid detection should operate so that the mean value of grid bias displacement, taken over a single high frequency period, should be directly proportional to the mean amplitude of the high frequency wave, sign not being taken into account. (On this basis the mean amplitude of a sine wave over one period is not zero, but $2/\pi$ times the maximum amplitude.) This ideal operation is not actually achieved, since the instantaneous value of the grid bias is controlled by the amplitude of the high frequency oscillation immediately preceding that taking place at any moment; there is thus a time lag.

This is illustrated qualitatively in Fig. 6. Perhaps some may find the process of distortion easier to conceive in terms of the impedance of the grid circuit of the valve. Since the grid assumes a charge of electrons increasing as the amplitude of the applied high frequency increases, the impedance of the grid circuit increases with amplitude, an effect which shows itself in distorting the audio frequency envelope of the high frequency wave. The ideal case is, of course, more nearly approached as the value of the grid leak is reduced—that is to say, as the conductance is increased. Unfortunately, the greater the conductance, the weaker are the signals, so that in practice, a certain amount of asymmetric distortion is always experienced with grid leak detection.

Other Types of Distortion.

As has been already mentioned under the heading of frequency distortion, the use of radio frequency reaction in receiving circuits results in an effective reduction in resistance of the circuit into which the reaction operates, with a consequent reduction of admping. An obvious result of this is that the high frequency oscillations will tend to persist after the actual cessation of the impressed E.M.F. due to the received signal. The wave shape of the audio frequency envelope of the modulated wave is thus changed, and frequencies are introduced into the output of the set which were not initially present. This may be observed on any set possessing reaction, and appears as a harsh grating

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noise; it does not appear markedly, however, until the reaction has been increased almost to the point at which the set begins to oscillate.

There are a variety of other considerations, many of which are almost negligible, and some of which are not yet completely understood. Among these may be mentioned: the night effect, which has been observed on cretain wave-lengths, and which results in the preferential transmission of certain frequencies; also the effect of land configurations and local screening conditions.

The radiation and reception of sound by devices whose dimensions are commensurate with the sound wave-lengths involved is also a problem which some have considered it worth while to investigate.

The question of interference is properly one which should be included under the heading of distortion. The measuring of interference and the assessing of its effect are themselves of so great importance as to constitute almost a separate science. Here we will only touch on two sources of interference considered broadly under the headings of atmospherics and parasitic noises.

Atmospherics are caused by thunderstorms or other sources of natural electric discharges, the nature of some of which has not yet been identified. Parasitic noises may be of two kinds. Those resembling atmospherics may be caused by other stations, by sources of power supply, by electric railways, and a number of other sources; mercury arc rectifiers are a prolific source of this trouble. The second kind are serious only when small volumes of audio frequency energy are being handled, and may be due to internal leakages in valves, external leakage in the circuit, or in the case of bad handling or workmanship may be due to local action in the high tension battery, or to bad contacts. Microphone noise might also be classed as a parasitic noise, inherent in some degree to all microphones depending on changes of resistance in carbon granules and the like. The modern microphones in use at broadcasting stations, however, entirely remove this source of trouble. The amount of interference tolerated depends naturally on the nature of the transmission as well as on the nature of the interference, and although certain standards of tolerance have been set, no universally applicable figures are yet available.

APPENDIX I.

The Process of Modulation and Detection.

Ideally the process of modulation should consist in making the amplitude of a high frequency carrier wave at any instant such a function of the amplitude of a modulating audio frequency wave that the modulating audio frequency wave may be re-obtained by a process which we may call detection.

The method most commonly employed is illustrated in Fig. 7, where a sinusoidal audiofrequency wave has been made to modulate a sinusoidal high frequency wave producing a resultant wave whose form is revealed by inspection to be—

$$e = E \sin ct + KE \sin vt \sin ct \quad \ldots \quad \ldots \quad (1)$$

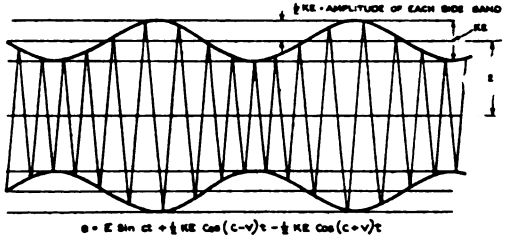

Fig. 7.

In this case $100K$ represents the percentage modulation. By an ordinary trigonometrical transformation this may be written—

$$e = E \sin ct + \frac{KE}{2} \cos (c-v)\, t - \frac{KE}{2} \cos (c+v)\, t \quad (2)$$

(Carrier) *(Lower Side Band)* *(Upper Side Band)*

Thus each initial audio frequency component is represented after modulation by two radio frequencies, one greater than the carrier frequency by the amount of the audio frequency, and the other less than the carrier frequency by this amount. The two spectra of radio frequencies obtained by the modulation of a radio carrier frequency by an audio frequency spectrum are called respectively the upper and the lower side band.

It appears fairly evident that any process of detection must take advantage either of their mutual difference in frequency or else of their difference from the carrier frequency.

Actually, we take advantage of the difference between the carrier frequency and the side band frequency. The ideal method of detection is straight line rectification, which would be intrinsically distortionless; in practice many available methods of detection involve the use of apparatus whose effective output *versus* input characteristics are curved. If we consider the simplest form of detection, which is by a crystal, this is not necessarily so, but in the case of a valve operating on the curved portion of its plate current-grid voltage characteristic it is evident that a certain amount of distortion peculiar to the method of detection must occur.

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The form of the vacuum tube characteristic shown in Fig. 8 is parabolic, of the form—

$$I_B = \mu (V_g + E_R)^2 \qquad (3)$$

If E_g = the grid bias and we superimpose a wave of the form—

$$V_g = e = E \sin ct + \frac{KE}{2} \cos (c-v)t - \frac{KE}{2} \cos (c+v)t \qquad (4)$$

on the grid voltage, then

$$I_B = \mu \left[(E_R - E_g) + E \sin ct + \frac{KE}{2} \cos (c-v)t - \frac{KE}{2} \cos (c+v)t \right]^2$$

$$= \mu \Big[(E_R - E_g)^2 + E^2 \sin^2 ct + \frac{K^2E^2}{4} \cos^2 (c-v)t - \frac{KE}{2} \cos^2 (c+v)t$$

$$+ 2 (E_R - E_g) E \sin ct + 2 (E_R - E_g) \frac{KE}{2} \cos (c-v)t$$

$$- 2 (E_R - E_g) \cos (c+v) t + 2 E \sin ct \frac{KE}{2} \cos (c-v)t$$

$$- 2 E \sin ct \frac{KE}{2} \cos (c+v)t - 2 \frac{K^2E^2}{4} \cos (c-v)t \cos (c+v)t \Big]$$

$$= \mu \Big[\text{Direct current} + (2 \times \text{carrier } f) + (2 \times \text{lower side band } f) - (2 \times \text{upper side band } f)$$

$$+ \text{carrier } f + \text{lower side band } f. + \text{upper side band } f.$$

$$+ 2E \sin ct \left\{ \frac{KE}{2} \cos (c-v)t - \frac{KE}{2} \cos (c+v)t \right\}$$

$$- 2 \frac{K^2E^2}{4} \cos (c-v)t \cos (c+v)t \Big] \qquad (5)$$

and neglecting the radio frequency terms which we do not require, we are left with

$$\mu \Big[\tfrac{1}{2} KE^2 \left\{ \sin (2c-v)t + \sin vt - \sin (2c+v)t + \sin vt \right\}$$

$$- \tfrac{1}{4} K^2E^2 (\cos 2ct - \cos 2vt) \Big] \qquad (6)$$

$$= \mu \Big[\tfrac{1}{2} KE^2 \sin (2c-v)t - \tfrac{1}{2} KE^2 \sin (2c+v)t + \underset{\text{(audio frequency)}}{KE^2 \sin vt}$$

$$- \tfrac{1}{4} K^2E^2 \cos 2ct + \underset{\text{(double audio frequency)}}{\tfrac{1}{4} K^2E^2 \cos 2vt} \Big] \qquad (7)$$

We thus arrive at the convenient fact that the percentage of undesired double frequency (of the required audio frequency) is one-quarter of the percentage modulation. A further fact is that the double frequency is caused by inter-modulation between the two side bands. Finally, we see from step 5 to 6 that the audio frequency characteristic may be preserved if only one side band is transmitted.

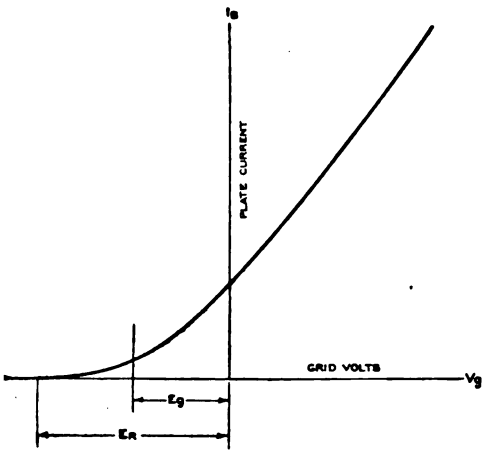

Fig. 8.

A point which is not shown by the above analysis is that there is mutual inter-modulation among the frequencies of one side band. Since the depth of modulation normally employed is less than 20 per cent. these effects are generally negligible as regards the sustained value of the combination tones. Even if over-modulation does not occur, an instantaneous peak voltage which causes 100 per cent. modulation will give rise to a 25 per cent. double frequency term on detection and combination tones dependent on the amplitude of the various component frequencies present. By supplying a carrier locally at the receiving end and so decreasing the effective depth of modulation they may be made as small as required; this method has the disadvantage, however, that since two side bands are generally transmitted, any difference between the local carrier and the original carrier causes differences between the detected audio frequencies contributed by each side band. The application of the superheterodyne or double detection principle may be made to obviate this disadvantage.

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A Note on the Cathode Ray Oscillograph. [R388

The essential feature of the cathode ray oscillograph—the use of a beam of electrons as the moving part—is by no means new, as it has for many years been employed in what is known as the Braun tube. This tube was, however, seldom used outside the best equipped research laboratories, because of the very considerable difficulties attendant upon its operation.

Both the Braun tube and the cathode ray oscillograph are operated as follows: the beam of electrons may be deflected in any direction by applying an electric or magnetic field across the beam near its source. Deflection occurs in the same direction as the electric field, and at right angles to the direction of the magnetic field.

If two fields are applied in two directions at right angles, then the path traced by the end of the beam is the curve in rectangular co-ordinates of the relation between the two fields at any time. If the two fields are cyclic and synchronous the beam traces the same pattern repeatedly, so that a stationary curve is in effect obtained. Special arrangements (such as those described in Appendix III.) permit of a stationary figure being obtained when time is one of the variables, provided the other is cyclic.

With the Braun tube, these principles of function are brought about by the arrangement shown diagrammatically in Fig. 9. The electron beam is derived from a high-voltage gas discharge, from some such electrostatic machine as the Voss or Wimshurst. The tube is a form of the high vacuum type having at one end a cathode from which the cathode beam is projected. Two baffle screens *A* limit the dimensions of the beam, which falls on a screen *B* of fluorescent material. The ray shows as a bright spot on the screen. Deflection of the beam is obtained by placing on either side of the neck of the tube a pair of coils traversed by an electrical oscillatory current. The line of light so produced may be examined by some such device as a rotating mirror. The Braun tube requires a constant voltage from 10 000 to 50 000, so that the operating gear is costly and cumbersome. The focusing of the ray is brought about by the use of "striction" coils, or some other producer of a powerful field.

The cathode ray oscillograph differs from the Braun tube in that the source of electrons is a hot filament. This makes it possible to obtain a sufficiently dense beam, travelling at a convenient velocity, with use of the comparatively low anode potential of 250-400 volts. The sensitiveness of the apparatus is thereby increased and the auxillary gear necessary for the working of the tube is correspondingly simple.

A photograph of the tube, fitted to the bayonet socket made for the purpose, is shown in Fig. 10, and the internal construction is explained more clearly by Fig. 11. In the latter figure, the small internal glass tube contains a length of oxide-coated filament (*f*) heated when in use by a 4 or 6 volt accumulator; from 1.2 to 1.5 amperes are consumed when the beam of electrons is properly adjusted. The small tubular anode (*a*), from which the beam issues, is about 10 mm. long. The current to the anode is about half a milliampere. A shield *S* is inserted between the anode and the filament, and has a small hole in the centre. The end of the filament is bent round to a circular form just larger in diameter than the hole in the screen, so that the back bombardment on to the filament of positive electrons is prevented, and the life of the filament is thereby increased to about 200 hours. The filament is drawn in detail in Fig. 12. Above the anode (*a*) are mounted two pairs of deflecting plates *Px* and *Py*, at right angles; one plate of each pair is connected to the anode. The potentials to be studied are connected between the anode and the other plate of each pair.

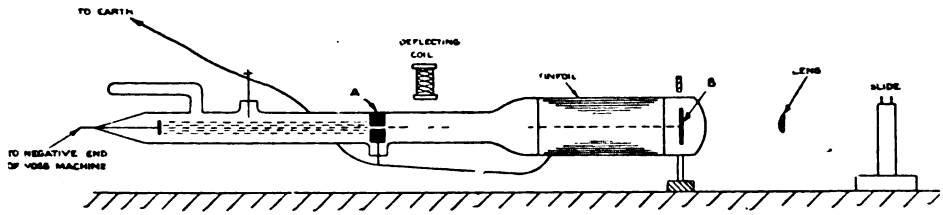

Fig. 9.

The large end of the tube is coated on the inside with a mixture of calcium tungstate and zinc silicate, so that where the beam strikes this screen fluorescence is obtained of such a colour as is bright enough for clear visual examination, and yet contains enough blueness to be fairly active photographically. The brightness of the spot is increased as the anode voltage is raised, but at the expense of course of a certain amount of sensitivity, so that the actual anode voltage employed is best selected according to the requirements of the experiment in hand.

The focusing of the rays upon the fluorescent screen is cleverly brought about by the introduction of a small amount of gas into the tube—a suggestion due to Dr. H. J. van der Bijl, who, with Dr. J. B. Johnson, has been responsible for most of the development work on this tube.

The part which the gas plays depends upon the difference in the mobilities of electrons and positive ions.

Some of the electrons in the stream forming the "cathode ray" in passing along the tube, collide with gas molecules and ionise them. Both the colliding electrons and the secondary electrons leave the beam, but the heavy positive ions receive

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very little velocity as a result of the impact, and drift out of the beam with only their comparatively low thermal velocity. It therefore happens that an accumulation of positive ions form a field surrounding the "cathode ray" which tends to pull the electrons inwards. Before the beam is focussed however the mutual repulsion between the constituent electrons must be overcome; this would occur when the number of positive ions in the stream equals the number of electrons. Also the original divergence in the beam must be overcome. Assuming this to be one degree from the axis and the electron current to be 2×10^{-5} amp. calculation shows that the radial field required to pull the beam to a focus at a distance equal to the length of the stream in the tube is about 1 volt per cm. This field strength is produced with fields of ordinary intensity if there are four positive ions for each electron in the stream.

When the current is increased, the total positive ionisation of the beam increases, the field around the beam becomes stronger and the electrons are brought to a focus in a shorter distance. The focussing of the beam therefore is brought about merely by adjusting the filament current.

With a 300 volt anode battery, a difference of potential across the deflecting plates of 10 volts causes a deflection of the luminous spot of about 1 cm. If small coils of wire are arranged on opposite sides of the outside of the neck of the tube, in the same plane as one pair of the plates, the deflection due to 1 ampere turn is about 1 mm.

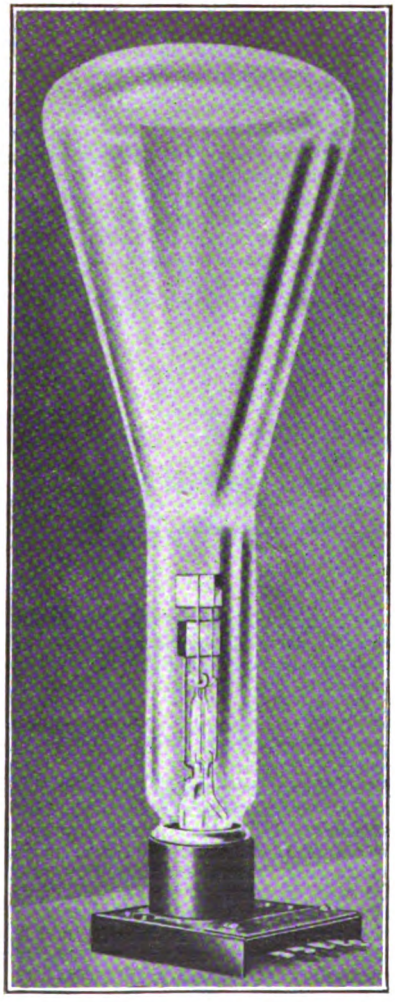

Fig. 10.

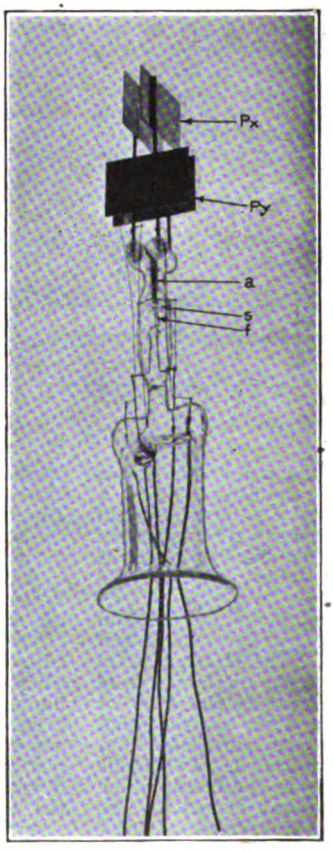

Fig. 11.

Fig. 12.

(To be concluded.)

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Some Notes on 20-Metre Work.

By E. H. Robinson (2VW). **[R545·0124**

WIRELESS experimenters are beginning to take a practical interest in the utilisation of wave-lengths below 40 metres. Wave-lengths round about 20 metres, especially, form a centre of interest, as American amateurs are allowed the use of this wave-length, which is therefore convenient for transoceanic experiments.

Although 20 metres is a very short wave-length compared with those with which we are more familiar, the same general laws hold for the radio frequency circuits involved. The only thing is that the ordinary H.F. effects are greatly exaggerated, and a little extra care is required in connection with certain points. Important things to remember are :—

1. The inductance of a straight wire is quite considerable. The thinner the wire the greater the inductance per unit length. Long connecting leads tend to become H.F. chokes.

2. Incidental stray capacities have a greater effect. The currents sometimes induced in short conductors apparently free at one end appear quite uncanny.

3. Mutual inductive and capacitative coupling between one's H.F. circuits and seemingly well-removed stray conductors in the same room may be quite large.

4. The damping effect of poor dielectrics is pronounced.

5. It is probable that at a frequency corresponding to the wave-length of 20 metres the time of travel of an electron between the electrodes of a thermionic valve is beginning to become comparable with the time of oscillation (1/15,000,000 sec.). If this is the case one would expect to find secondary effects not observable on longer wave-lengths.

Short-Wave Calibration.

The first problem encountered in commencing work on short wave-lengths is to know when one's circuits are tuned to the required wave-length. Some form of wave-meter or calibrated receiver is practically indispensible. A simple heterodyne wave-meter of the Hartley oscillator type has been found very serviceable.

Many experimenters will have hit on the idea of using the harmonics from a local broadcasting station operating on a known wave-length as standard points for calibrating their sets. Since a complete set of exact multiple harmonics is present, carrier-waves will be heard on wave-lengths of exactly $\frac{1}{2}$, $\frac{1}{3}$, $\frac{1}{4}$, $\frac{1}{5}$, etc., of the fundamental wave-length. Harmonics beyond the fifth or sixth, however, become rather weak and are apt to be confused with other transmissions.

If, for instance, we are situated in London,

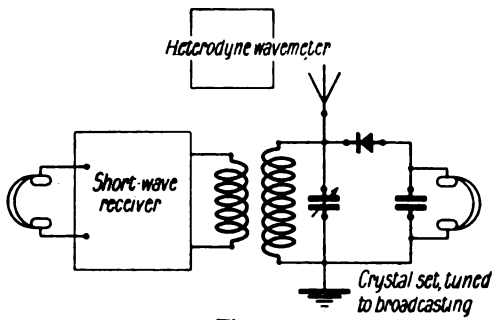

Fig. 1.

and are employing the harmonics of 2LO, whose fundamental is about 365 metres, we shall have to follow the harmonics down to about the eighteenth in order to calibrate a 20-metre receiver. The harmonics here are not only very weak normally, but are close together (about 1.3 metres apart), so that there is a great liability for errors to be made. It has been found, however, that the following simple method allows very strong harmonics to be heard to the practical exclusion of other signals. Fig. 1 shows the scheme.

An ordinary crystal receiver is connected to aerial and earth and is tuned to the local broadcasting station; the crystal detector is adjusted to give the best rectification as judged by the signal heard in the phones associated with it. Owing to the rectification, and consequent distortion, of the incoming carrier wave, a complete series of exact multiple harmonics are produced in the crystal set, and these may be heard quite strongly in an oscillating short-wave receiver placed within a few inches of the inductance of the crystal set. The reason for the

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production of these harmonics has been comprehensively treated in a recent article by Mr. Colebrook in this journal.

By means of a short wave receiver with interchangeable coils the harmonics can readily be followed from the fundamental down to the twentieth harmonic. It is necessary to exercise some little care not

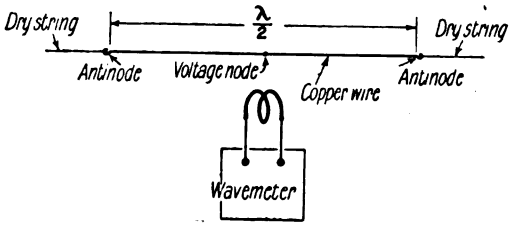

Fig. 2.

to miss a harmonic nor to count the same one twice in changing one's coils when the bottom of the existing range has been reached. It is convenient to use a heterodyne wavemeter to "hold" the wave-length while any change is being effected in the short-wave receiver. In fact, it is a good plan to calibrate the wavemeter in the same sitting. Feeble intermediate notes may be heard due to harmonics in the wavemeter or receiver, but the required harmonics of relative frequencies 1, 2, 3, 4, 5, etc., are comparatively strong and easily distinguished.

Another and more straightforward way of finding one's wave-lengths on these short waves is to employ one of the methods in which stationary waves are set up in straight wires. Wave-lengths are measured directly by a tape-measure or metre rule. The Lecher wire method is the best-known accurate method, but this merits a complete article to itself. In order to obtain an approximate calibration of a wavemeter between 15 and 23 metres, the following method was used; it is extremely simple, takes only a few minutes to fit up and works quite nicely.

A straight length of copper wire is suspended horizontally (see Fig. 2), and is kept taut to avoid sag. The wire is held by lengths of thin, dry string attached to its extremities, the attachment being effected by forming the ends of the wire into the smallest possible hooks. It is best to perform the experiment out in the open as far away from obstacles as possible, and the wire should be at least five feet above the ground. The ideal to aim at as far as possible is a perfectly straight conductor completely isolated in space and out of the influence of other conductors and dielectrics. Under these conditions the velocity of electric waves in the wire is, for approximate purposes, the same as that in free space.

When the wire is responding at its fundamental natural frequency there will be a potential node in the middle and potential antinodes at the ends; the resonant wave-length of the wire will therefore be equal to twice its length. If we wish to obtain a wave-length of 20 metres it is only necessary to measure off a length of wire 10 metres long. It is now only necessary to find when our wave-meter is in resonance with the wire.

With a heterodyne wavemeter having telephones in the anode circuit this is easily enough accomplished by the "double click" method. The oscillating wavemeter is coupled to the middle of the wire by holding it so that the plane of the turns of the wavemeter coil is in the same plane as the wire. This is indicated in the sketch. The dial of the wavemeter is slowly rotated until the passage through resonance is indicated by a double click in the telephones. Often the two clicks are so close together as to sound like only one; if this is the case, so much the better. The wavemeter should be held as far from the wire as is possible without losing the

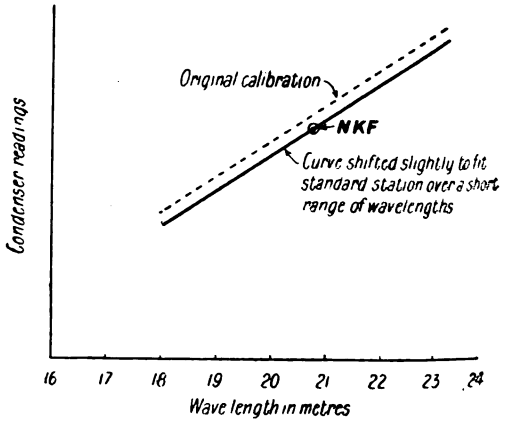

Fig. 3.

indication. Usually it is sufficient to have the wavemeter within a foot or two of the wire. The operator's body, the batteries, telephone leads, etc., should be kept as much in the background as possible.

By repeating the experiment with various

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lengths of wire it is possible to plot a number of points for the calibration curve of the wavemeter. As to the guage of the wire used, No. 22 S.W.G. seems to answer well.

The calibration curve obtained for the wavemeter may look quite smooth and consistent, but this is no guarantee that it is not as much as half a metre out. There is plenty of room for small errors, and it is up to some of the precise merchants, such as the N.P.L. folk, to give us a hand. The calibration of the writer's own wavemeter does not quite agree with the American naval station NKF, who insists that it is on 20.8 metres. The discrepancy of 50 centimetres is rather difficult to account for, but considering NKF's probable resources for accurate calibration, it ought to be correct, even if it isn't. The curve of the writer's wavemeter has therefore been corrected as illustrated in Fig. 3. The dotted line is the original calibration of the wavemeter as obtained by the straight wire method.

As the wavemeter condenser was of the square-law variety and only used over a limited part of its range a very nearly straight line was obtained. The American station NKF was tuned in on a receiver and since the wave-length (20.8 ms.) was known an independent point was plotted on the curve sheet. This fell a little off the original lines, so the thick line was drawn through NKF's point parallel to the dotted line. Provided that NKF is accurate this thick line should furnish a fairly accurate calibration over a short range of wave-lengths.

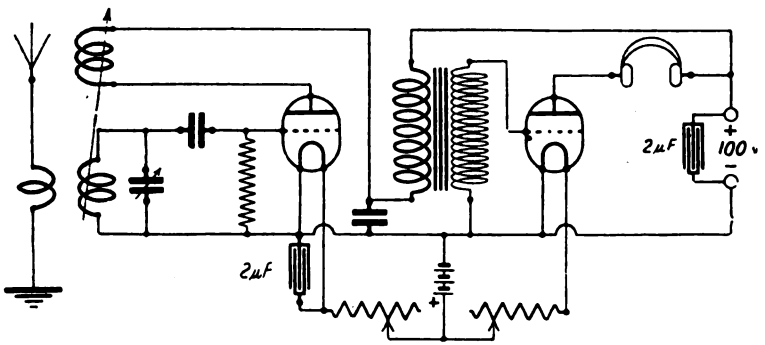

Fig. 4.

Reception.

The reception of C.W. signals between 18 and 40 metres does not present any very great difficulty provided that the set is arranged with due respect to the extremely high frequencies involved. This implies keeping all leads carrying H.F. currents as short as possible, using a reasonable minimum of dielectric in the form of coil-holders, valve-holders, etc., and, above all, confining the H.F. currents rigorously to the tuned circuits and detector valve and not allowing them to wander round stray paths such as telephone leads or the L.F. amplifier.

These stray-path effects are often rather surprising and are just as important in causing "dead spots" in tuning and preventing the set from oscillating as the more generally known effects due to dielectric losses. In fact the "low-loss" idea is frequently overworked; it is not necessary in order to receive on 20 metres to build a set which is thoroughly useless on other wave-lengths. The writer finds that a reasonable amount of good quality ebonite, in the form of standard coil-plugs, etc., has no very serious effect. A "Polar" coil-holder has been found satisfactory, the arm with the universal movement allowing a very nice control of the magnetic reaction. Both fixed and movable sockets have been removed from their original base and incorporated with the base of the set.

There is no need to use any unusual circuits for the receiver. H.F. amplification seems to be right out of the question at present, so we have to fall back on the regenerative detector and L.F. amplification. Owing to the confusion of names and circuits occasioned by the popular Press the circuit used by the writer is reproduced in Fig. 4 without apology. An "untuned" aerial is used. The grid circuit of the detector comprises a plug-in coil tuned with a square-law condenser having a maximum capacity of .001μF. This condenser has a vernier plate provided with a long manipulating handle. The capacity may seem rather large for short-wave work, but only the lower 40 degrees of the range are used for 20 metre work.

It is rather convenient to use a large tuning condenser, as the effects of varying stray

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capacities, such as the operator's body, are reduced, and in addition to this the vernier plate has a very fine tuning effect, enabling C.W. heterodyne notes to be held with comparative ease. The grid tuning inductance is a flat spiral of 5 turns of No. 14 bare copper wire, the diameter of the outside turn being 3 in. and that of the inside turn 1¾in. The coil is fitted to an Igranic plug and is self-supporting. The reaction coil is of a similar type but with one or two more turns. The detector valve and its associated coils are mounted compactly together and well away from the L.F. amplifier. By-pass condensers are placed wherever they may seem necessary.

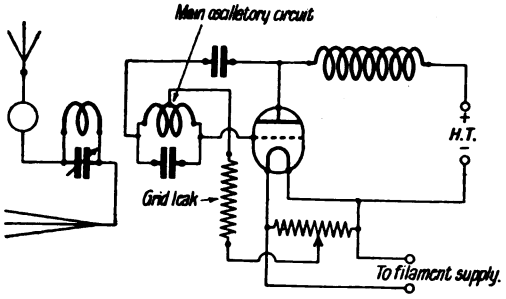

Fig. 5.

Ordinary four-pin valves in reasonably good sockets will oscillate quite well, but it was found a distinct advantage to use a valve of the V-24 type, as the connections to grid and anode can be very much shortened, this enabling the set to oscillate more easily and allowing tighter coupling to the aerial to be used. The connection between the grid and the top of the grid circuit is made by a short copper-foil strip which itself incorporates the grid condenser. This is effected by having the strip in two portions overlapping with mica insulation between them. Connections to the grid and anode of the valve are soldered directly on to the lugs, thus doing away with the clips.

It pays to boil things down like this on 20 metres. In the writer's own experience a stage of L.F. amplification is a very decided advantage, in that it enables signals to be heard which would be inaudible on the detector valve alone. For higher wave-lengths this is a controversial point with some experimenters, but there does not seem to be much doubt about it for ultra-short wave-lengths. The reason may lie in the greater absence of atmospherics and general QRM.

In connection with leaky-grid rectification below 30 metres a very peculiar difficulty is likely to occur. Best detection on ordinary wave-lengths is usually obtained by leaking to the positive end of the filament. If this is attempted on about 20 metres the set may tend to howl when just oscillating. If the reaction is coupled tightly so that the set oscillates furiously the howl disappears; it is just when the set is in the most sensitive condition for picking up faint C.W. signals that this aggravating noise occurs. The trouble can be cured usually by taking the grid-leak to the negative end of the filament, but this may mean a slight sacrifice of signal strength. The effect referred to seems in some way dependent on the very high frequency of the oscillations, the grid current, and to some extent on the presence of the low-frequency amplifier; it never occurs on long wave-lengths. Can anyone explain it? Is it anything to do with the grid-current electrons moving too slowly?

Transmission.

Here we come to the side of the subject which will offer problems to all transmitters and humiliation to many. It is easy enough to make a power valve oscillate on wave-lengths of the order of 20 metres. It is not so easy, however, to obtain a pure, steady C.W. note. Also how are we going to operate a valve efficiently without having an amp of H.F. current or two going through the grid and plate seals?

Dealing first with the power valve, the writer has a strong preference for the low-impedance type of valve for short waves. For one thing they oscillate more readily and require little or no "anode tap" winding. With a high-impedance valve it may be impossible to introduce the optimum amount of anode inductance without raising the wave-length above the desired value; one cannot use much of a closed circuit condenser, with the result that the valve capacity becomes the main closed-circuit condenser with heavy H.F. currents circulating through it. Again, the high-impedance valve must be operated with high D.C. and high H.F. potentials on the anode and therefore the glass is subjected to large dielectric strains. On the other hand a low-impedance valve may be operated in conjunction with a

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closed oscillatory circuit with a smaller inductance and a reasonably large condenser, through which the main bulk of the high-frequency current flows instead of through the valve.

The simplest form of Hartley circuit seems to be as satisfactory as anything for short-wave transmission—at any rate if a valve of fairly low impedance is used. The arrangement shown in Fig. 5 has been found satisfactory. The H.T. is shunt-fed. It will be seen that the middle point of the Hartley circuit is not anchored to the filament with a condenser but is free except for the grid-leak connection. If the middle of the circuit is anchored at all this must be done at the exact nodal point of the circuit; but there does not seem to be anything gained by shunting the grid-leak. The aerial circuit is loosely coupled and tuned by a .000 5 variable condenser in parallel with two turns of wire, this working quite well in spite of the fact that that unloaded aerial system has a fundamental wave-length of about 60 metres. No method of keying is shown as the best method has not yet been decided upon.

A few details of the construction of the Hartley circuit may be of interest as showing one way of doing things. This is made up according to the writer's own private ideas about low-loss circuits for short wave-lengths, and comprises four turns of thick copper strip 6 in. diameter spaced half an inch apart. The ends are soldered to two parallel flat copper plates 5½ in. square and about ¼ in. apart, forming an air condenser. This is illustrated in Fig. 6. The lower sketch in this figure shows how the spacing between the plates is maintained without introducing any solid dielectric between them. By varying the spacing, adjustments of wave-length may be easily made. The calculated capacity between the two copper plates only amounts to a few micro-microfarads, but this is in proportion to the values of capacity used in valve practice on longer wave-lengths.

Considerable trouble was at first experienced with mechanical vibration due to traffic in the street, etc. This set up relative vibrations between the condenser plates and between the turns of the inductance, with the result that the note had a continual wobble. The turns were bolted to ebonite spacing strips and the whole circuit was fixed firmly to a shelf, but this did no good. Finally the trouble was completely eliminated by hanging the Hartley circuit from the ceiling by a single rubber band. It was then possible to stamp on the floor or bang the walls of the operating room without affecting the note of the transmitter. Connection to the rest of the apparatus is made by means of fine copper wires which do not transmit mechanical shocks to any appreciable extent. It is necessary to avoid draughts, as these blow the Hartley circuit about and cause slight swinging of the wave-length.

It is much harder to obtain a pure C.W. note on ultra-short wave-lengths than on the longer ones, both in the case of D.C. generator supplies and rectified A.C. The difficulty is not insuperable. In the case of rectified A.C. it is usually just a matter of adding more condensers and chokes to the smoothing circuit. If A.C. is used for filament heating the problem is a harder one. Where an absolutely pure C.W. note is required and the filament does not take more than three amps it is best to use batteries. Most American amateurs seem to have solved the problem by not worrying about the note

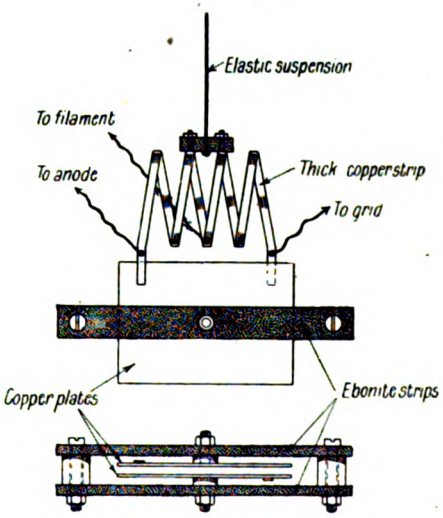

Fig. 6.

at all. This is not altogether a good plan in view of the interference at the receiving end from the ignition systems of passing motor-cars, with which a faint raw A.C. note is likely to become confused.

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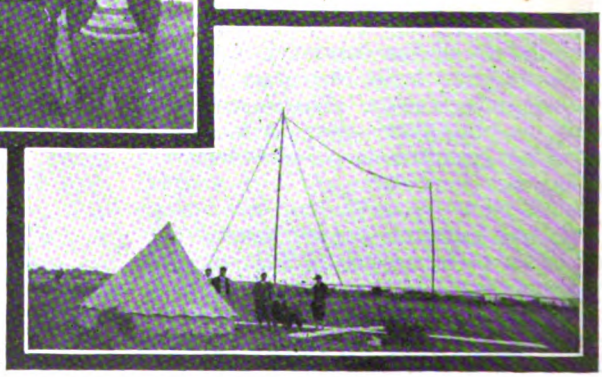
Wireless Field Work.

Successful experiments at Light 'Plane trials at Lympne.

AT the request of the Royal Aero Club and by the kind permission of the P.M.G., three transmitting and receiving stations were installed by Messrs. N. V. Webber & Co., Ltd., of Vale Road, Oatlands Park, Weybridge, Surrey, on the occasion of the Light Aeroplane Trials held at Lympne recently. By means of these stations, rapid communication between the aerodrome and the two turning points on the course—Postling and Hastingley—was maintained. These turning points were respectively about 4-5 miles from the headquarters station at the aerodrome.



A view of one of the stations, and (above) a group of the operators.

These two out-stations were similar in design, and each consisted of a 2-valve receiver and a single-valve transmitter, equipped both for C.W. and phone. Power was derived from large capacity dry-cell H.T. batteries, about 5 watts being drawn at 220 volts, giving an aerial current of .3 amps between 150 and 200 metres. Both transmitter and receiver were combined in one instrument.

Tents were erected in which the apparatus was installed, and two bamboo poles, 15 ft. in length, were tied together and used for aerial masts. This gave a height of about 25 ft., and a single-wire aerial, 75 ft. long, was employed. A single-wire counterpoise, immediately under the aerial and 3 ft. from the ground, was used instead of an earth system, an earth pin being used for the receivers.

At the headquarters station two aerials at right-angles were used—one for transmission and the other for reception. Two receivers were connected in series—one tuned to Hastingley (6ZB) and the other to Postling (6ZC). By this means reports from both out-stations were received simultaneously and without difficulty; and as the two out-station receivers were tuned to headquarters, orders could be transmitted to them as desired.

Conditions during the trials were by no means ideal; heavy rain was experienced while the apparatus was being installed, and severe thunderstorms occurred on the Saturday. Moreover, the Hastingley station had to be moved a distance of some 1¾ miles, owing to an alteration in the course for one of the day's trials.

However, in spite of these drawbacks, everything was carried out according to schedule, phone being worked nearly all the time, with C.W. as a stand-by when static and oscillations from curious local B.C.L.s made phone reception unreliable.

Communication was constantly maintained between out-stations and headquarters at the aerodrome, and there was great satisfaction at the efficient way in which the arrangements worked; reports being rendered to the Royal Aero Club officials, not only of the progress and position of the competing machines, but also of the safety of the pilots and passengers when forced landings had to be made. Removal of the aeroplane, when these occurred, was also greatly expedited.

Finally, mention must be made of two definite conclusions which emerged. Firstly, all field stations using portable aerials *must* have loose-coupled aerial circuits—both on transmitters and receivers; and secondly, aerial and counterpoise leads-in *must* be taken in at the top and bottom of the tent respectively and firmly staked to prevent swaying—great difficulty being experienced during the preliminary tests in keeping the wavelengths constant.

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Long-Distance Work.

By Hugh N. Ryan (5BV). **[R545·009·2**

SINCE its inception DX work has passed through a number of phases. As far as this country is concerned they were firstly, transmission between different parts of Britain; secondly, work with France, Holland, Denmark, etc.; thirdly, work with the United States; fourthly, the world-wide communication of to-day. In the earlier days of the work, one sometimes heard the question "What will happen when we can transmit all over the world?" To-day that question actually arises, and with it we enter another phase of the work—the time when mere distance is not our aim, and a station will only be credited with the use which he makes of his results and observations, and not with the results themselves.

This doubtless should always have been the case, but it is common knowledge that many of our best stations were aiming solely at "distance," and lists of large numbers of stations worked, without worrying much about the technical interpretation of their results. Far be it from me to decry their work, which has brought about the very desirable state of "world QSO" that now obtains. But that stage of the work is over, although I still receive reports for these columns, saying that a station has worked, say "25 Yanks in one night." This may be a diverting way of spending a night, but one wonders whether anything useful was done in conjunction with any of the twenty-five?

All of which is a prelude to saying that I propose altering slightly the scope of these notes, to make them more useful under the new conditions. Briefly, I propose devoting less space to the doings of the well-known, high-power stations, except when they accomplish something of special technical interest, and dealing more with low-power and definitely experimental work. To this end I want particularly to ask for reports from the many lower-powered stations, who are known to be doing a lot of work, but who perhaps, have been afraid that their reports would look insignificant beside those of the "super DX-merchants."

Since all European stations may now be regarded as "local," I hope to include (at the request of a number of Continental readers) the work of Continental stations in these notes, wherefore I ask for reports from foreign readers.

Now for the reporting. The month has been one of steady work on the 45-metre wave, with practically nothing doing on 90 metres, and not very much on 23.

2NM (900 watts) is always fairly weak at 5BV (10 miles), his phone being at times quite hard to follow on one valve. At Newcastle he is stronger than this normally, but at about midnight his signals suddenly disappear completely, or become so weak as to be unreadable. Two hours later he suddenly comes back, at about double strength. During the time he is inaudible at Newcastle he is very strong in America.

2VX (only a few watts) is of tremendous strength, a genuine R9, at 5BV (about 400 miles) late in the evening, and suddenly disappears at about 2245 G.M.T. His time of reappearance has not yet been noted.

Dutch PC7 is very strong at 5BV in the forenoon, and suddenly disappears at about 1145 G.M.T. These examples will serve to indicate the sort of phenomena experienced. In addition to this effect, it seems that a station at a short distance (100 or 200 miles) can be of widely different strengths at two other stations situated close together. For example, 2IH (Yorks) is of very different strength at 5LF and 5BV at the same time, all possibility of difference in receiver sensitiveness being eliminated. I should welcome other observations on these effects.

As to the more remote stations, the Americans are strong from before midnight until some hours after sunrise, the 1st, 2nd, 3rd, 4th and 8th districts being very easily worked on 50 watts.

The New Zealanders and Australians are to be heard between 4 and 8 a.m. G.M.T. approximately, and are also fairly readily worked, the only bar to every station above, say, 50 watts working them almost daily being that there are not enough of them to go round.

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Other countries now regularly heard on 40 metres, or thereabouts, are Mexico, Brazil and Chile, and we hear the Philippine intermediate (pi) in calls from Chilian stations, but have yet to hear it coming back the other way.

The Post Office have entered the select company of "DX night-birds" with their station 5DH. He is notable for his propensity for CQ calls of enormous length, and for the worst note ever heard in London. He seems, however, a useful DX station, having been heard a great deal in America, and by South African A4Z.

A number of other Londoners are in regular operation. 6LJ recently worked z2AC and twelve Americans in one morning and has heard several stations in Chile, Brazil, Argentine and Java.

6QB heard NRRL (F. H. Schnell on the U.S.S. "Seattle") when he was in Melbourne Harbour. His own transmitter, the aerial current of which he is unable to measure, continues to be heard occasionally in U.S.A.

2GO recently worked 4SA (Porto Rico) for 25 minutes with 12 watts input.

5BV's mast, which for some time has been trying to resolve itself into a very complicated Fourier series, has proceeded to the limit and is now a "discontinuous function." The aerial is slung up temporarily, part being below the counterpoise, but the only difference (on 45 metres) is that some of the Americans report stronger signals!

2XV is even more unfortunate with masts. Mine did stay up for two years, whereas 2XV has just put up his fourth this year. He is working with 3 watts input, and with this he covers Europe as far as Germany.

5SI, who in the past has performed wonders with very low powers on 90 metres, is now working on 45, with less power than ever. Tests (on different days) with u1PL and u1CMX have resulted in communication with ¾ watt input. He contemplates a QRO to 5 watts for New Zealand!

6JV's work during the past month has been mostly on the reception side. He has followed the ARRL 20 and 40 metre tests, noting variations of strength of the stations at different times of the night. On the transmitting side, he is attempting to get as pure a note on 45 metres as he does on the longer waves. Like many others, he has not yet entirely succeeded. An H.T. accumulator is on the way.

2VR (Bristol) is a "dry cell" station using 3 watts, and has worked many parts of Europe on 100 metres. 5FS, also of Bristol, is still on 90 metres at the time of writing, but is about to start on 45.

6VP has just completed his first month as a transmitter, and (believing in starting from the beginning) he systematically covered the British Isles with 2½ watts before increasing to 10 watts.

2IH is in the curious position of working regularly with Brazil, while he had not yet succeeded in working with the United States. Another Yorkshire station, 2VO, has worked BSM (Palestine) and 1DH (Mosul) with 3 to 4 watts, 1DH reporting him as the best British station heard (100 watters, please note).

6TD is regularly to be heard on 45 metres, where he is conducting a great deal of useful DX work, being the most active Welsh station at the moment. 5OC is another very active Welsh station, who has worked chiefly on the longer waves, but hopes soon to be on 45 metres. He has worked nearly every country in Europe and several American stations.

5NJ, of Belfast, is now in regular operation though only, as yet, on dry cells. During his first month of operation he has worked most of the nearer European countries on 7 watts. He will be using higher power, with a generator, in October.

The only foreign report to hand is that of Danish 7EC. He worked stations in five American and two Canadian districts on 90 metres before descending to 40. On the latter wave he has worked Americans up to 6 000 miles, having a nightly schedule with u4SA. He has an automatic key for testing and sending CQ, which accounts for the varying "fist" of his station.

Readers will probably be interested to hear that the following schedules have been fixed by the British section of the I.A.R.U. for the exchange of messages between British stations. 0000 to 0015, daily, on 90 metres; 0015 to 0030, and 0730 to 0800, daily, on 45 metres—all times B.S.T. It is hoped that all stations will keep these periods clear for "inter British" work.

Every Sunday morning, at 0030, B.S.T., 5MO (I.A.R.U. British secretary) will send, on 45 metres, a report of I.A.R.U. work.

Please let me have next month's reports by 10th September.

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Investigation on Fading of Signals.

By S. R. Chapman, M.Sc. **[R113·1**

THIS investigation was undertaken by the Radio Research Board under the Department of Scientific and Industrial Research in the early part of last year. In the issue of the *Wireless World*, 12th May, 1923, an article was published inviting, through the Radio Society of Great Britain, the co-operation of amateurs in investigating the occurrence of this phenomenon during the reception of broadcasting and signals from other transmitting stations.

Pads of forms were issued to over 380 observers who were willing to assist in recording their observations and of these 118 have taken part.

A further article was published in the issue of 7th November, 1923, as an aid to observers when filling up these forms.

The following article is an analysis and report on the observations made during the period of July, 1923, to July, 1924, but before going into the details, it is necessary to make some general remarks on the records and to refer back to the system and method adopted in recording these observations.

In the first place, the 118 amateurs who have taken part are fairly widely scattered with regard to the British Broadcasting Company's stations, the majority being in England, a dozen or so each in Scotland and Wales, two in Ireland, four in the Channel Isles and one in Spain.

The majority of the observations have been taken on the B.B.C. stations, only a few observers having watched other transmitters, such as ship and shore stations, and thus all programmes of watches that have been specially arranged have been on the B.B.C. transmissions. A few observers have watched the U.S.A. broadcasting, and a note concerning their reports appears later in this article. A few have watched Ecole Supérieure and other Paris and Continental stations, but in these cases there has been no chance of comparing reports as no two observations have coincided in point of time.

All observers were asked to watch for periods of ten minutes or more, as shorter periods are hardly of any value in showing the general behaviour of the station, and to note the strengths on the forms, say, every fifteen seconds, using the figures "0" to "9" to denote various strengths. The gradation of the figures "0" to "9" and the type of form used for recording observations can be referred to in the issue of the *Wireless World* for 12th May, 1923.

As mentioned in previous articles, the greatest difficulty met with in this method of recording observations is in the programmes of the transmitting stations themselves. Most of the programmes are musical, and it is extremely difficult to decide whether a real "fade" has occurred or whether the diminution in intensity of the received signal is merely due to a pianissimo passage in the music, especially if the piece being played is unknown to the observer. Observers were asked to make notes as to whether they knew the piece or not, but very few have done so, making the analysis of the records still more difficult. This also applies if the transmission is a song; and in the case of speeches, observed change in intensity might be due to the raising or lowering of the voice, or any change in the relative position of the speaker to the microphone. Consequently, it should be stated here what has been considered for the purposes of this report as a definite "fade" when analysing the records.

In analysing an observer's report, the author has first noted what the normal strength of any transmitter is at his station. For example, say the signal strength has been designated by him as "7" or "8" during periods when the transmission has been steady with no "fading." In a subsequent watch it may be frequently recorded as dropping from the normal to "5" or occasionally "3," but it has been considered this may easily be due to pianissimo passages, or in orchestral performances a solo instrument for a few bars, and has not been reckoned as a "fade." When, however, the signal is recorded as dropping to "1" or "0," this may safely be taken as a definite "fade."

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Still more care has been taken in deciding what are "fades" when the normal strength is recorded as only "5" or "6" strength. It was found impossible to make any hard and fast rules to cover all the records owing to the variety of receivers used by the many observers.

One of the general statements that can be made with regard to all districts is that they all do experience fades at one time or another. There is no district of which it can be said no "fades" exist there. A few isolated cases have sent in records with no "fades" at all, but these observers have only watched one transmitter, and then perhaps only on a couple of evenings in one month. What has happened during the other twelve months of the period under report is not known, and so no inference can be drawn as to the behaviour of other transmitters at their receiver.

Another thing which is common to all receivers is that on reception from stations which can be heard before sunset, no fades are recorded until "sunset period." Many have recorded that a little before and during sunset a "mushiness" and unstable condition is noted, and then after this transition period from day to night the signal settles down.

This is very similar to the experience we have had as to the behaviour of the bearings of transmitters on neighbouring wave-lengths working under similar conditions, *i.e.*, over land, when direction finding, and further investigations are being undertaken to see if "fading" is always accompanied by a change of bearing or *vice versa*.

There is a difference, except at short distances when it is probably existent but inappreciable, in intensity between the strength of signal received during day and night from the same transmitter at any one station, the former being weaker. This has been the experience of the observers in their reports on the B.B.C. transmitters, and as mentioned in a previous paragraph, they find some stations are inaudible to them during the day. Distance is one of the main factors in this phenomenon, and the general experience is that transmitters situated 200 miles or more from the receiver are inaudible until after sunset. It has not been found possible when analysing the reports to discover any definite distance at which this effect occurs, but it can be stated to be somewhere between 160 and 200 miles, the former being audible. However, this general statement must be qualified by stating that not only is distance a big factor in inaudibility, but the amplifier used plays an important part. The apparatus used by the majority of observers agrees with the general statement, but if a highly efficient and selective amplifier is used, combined with directional reception, it is possible to hear a B.B.C. Main Station transmitter over 400 miles distant during daylight, although, of course, the intensity is extremely weak compared with the night strength obtained with such an amplifier.

It cannot be said in any single case that the signal strength of any one transmitter will be constant from night to night for a lengthy period at the same receiver; the strength may easily be below normal one night and perhaps the next or a few nights after, considerably above. However, there is no analogy between these changes of normal strength and "fading." For instance, an observer when watching one night may find that the best he can get from a transmitter after the most careful adjustment of his receiver is below its normal strength; he cannot assume that because of this he will experience very erratic signals and marked "fading." The opposite is just as likely to occur and the signal remain constant. Similarly he cannot assume the absence of "fading" should the strength be well above normal. Consequently there is no general principle to be laid down as to the relative change of normal strength of a transmitter from night to night.

One general consideration of interest is the comparison of the number of "fades" experienced with the bearing of the transmitter observed. Briefly, it may be stated that from the analysis of the reports received it can be shown that there is no particular compass direction in which there is a preponderance in the number of "fades" recorded.

Another general consideration to be taken into account is comparison of the number of "fades" with distances between transmitter and receiver. Again there appears to be no general rule governing this, excepting that no "fades" as defined in this paper, *i.e.*, audible changes in intensity, have been recorded over shorter distances than 50 miles, transmitters situated nearer to the observer than this can be reckoned as "non-faders." Examples could be given of signals "fading" from a transmitter at a

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certain observer's station and yet another observer situated at a greater distance from the same transmitter, records less "fading" or none. In this case, it can probably be shown to be due no doubt to the geographical features of the space intervening between the transmitter and receiver and that this plays the more important part.

One more general remark to be made on this analysis before proceeding with the more detailed part of the report, is that there seems to be no definite periodicity of the time intervals between each occurrence of "fading." During long watches no definite recurrence of fades at constant equal time intervals were observed, and from night to night, or even on the same night, fades may occur at both short and long intervals having no relation to one another. To give a better idea of these time intervals, an example can be cited where a group of fades occurred with a time interval between the maxima and the respective minima intensities of only a few seconds—*e.g.*, one record showed a group of four or five fades from "8" to "o" in times varying from 6 to 15 seconds—then the next real fade might be one minute from this group and the next say three minutes and so on. Also over long watches such as two or more hours no recurring periods could be traced with these groups of fades, the interval between them being unequal, sometimes two close together followed almost immediately by a fade to "o" perhaps lasting two minutes or more.

The analysis of these observations over this period of 13 months shows the fades to be very erratic in occurrence and type and to follow no general law, and to be independent of bearing of transmitter from receiver.

Now to consider the details obtained by the analysis of records sent in. At the beginning of the report it was mentioned that only 118 amateurs took part out of the 380 odd who requested that they might be supplied with observation forms. Of these 118 records, unfortunately, many had to be discarded as being useless. The reason for this in a few cases was that observers had watched stations, but according to their records never for more than five or six minutes at a time. Such records as these were discarded as the general behaviour of a transmitter cannot be judged from such little information, which frequently was limited to a record of the signal strength only at the beginning and end of the five minutes. Another reason for discarding some records was that they lacked any information other than that a fade occurred, and contained no note as to the moment it happened, or how frequently. Sometimes the record even omitted to mention the strength to which the signal faded, a remark only being made that the signal "Faded badly," or that there was a "Gradual fade."

Table I. (see next page) shows an analysis of the records throughout the period under review. By means of this table it is possible to trace any seasonal effect on the number of fades recorded, *i.e.*, whether they are more prevalent during the winter months than the summer. This table must be considered in conjunction with Table II., because it is obvious from Table I. that there were many more fades recorded during November and December, 1923, and January, 1924. However, at that time many more observers were working, and consequently more periods observed, although it will be seen from Table II. that the percentage is more or less of the same order.

ERRATA.

A few printer's errors occurred in our August issue, and we shall be glad if readers will note the corrections, given herewith.

(1) On p. 685, line 2, in Mr. R. M. Wilmotte's article "A Variable Resistance for Radio Frequencies" the word "nickel" should be "nickelin."

(2) The Dewey index number for Mr. Mines' article on p. 687 was given as R555.5, instead of R355.5.

(3) On p. 711, at the end of the description of Messrs. S. G. Brown's hand microphone and telephone transformer, we state that the price of the outfit is "rather high" and £11. We regret that we were misinformed, since the correct price is £7 7s.

(4) Our attention has been called to the fact that the address of the manufacturers of the "Harlie" detector—described on p. 712—has been changed to: Harlie Bros., 36, Wilton Road, Dalston, E.8.

(5) Finally, in the Appendix (p. 719) to Mr. Barton Chapple's article on the self-capacity of inductance coils, the formula for parallel circuits was given as :—

$$\frac{1}{(R + j\omega L)} = \frac{j\omega C_s + 1}{(R_0 + j\omega L_0)}$$

This should have been

$$\frac{1}{R + j\omega L} = j\omega C_s + \frac{1}{(R_0 + j\omega L_0)}$$

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Further remarks which should be made with regard to Table I. are that of the 118 observers who took part, no less than 44 reports were rejected as useless under the two headings mentioned above. Also it should be borne in mind that this table does not represent the total number of *fades* recorded throughout the 13 months. It will be seen that the total number of actual *periods observed* (column 1) is 2 022, and since frequently more than a dozen fades were recorded in one period, many thousands of fades are omitted as occurring in periods shorter than ten minutes in duration. It will be seen that periods are divided into those of 10, 30 and 60 minutes' duration. Here, again, many periods have been of, say, twenty minutes, *i.e.*, intermediate between 10 and 30 minutes. In these cases only the numbers of fades occurring in the first 10 minutes are considered, as this is the only way of showing fair comparison from month to month. Also, each period of over an hour's duration has fades shown in the two previous columns of 30 and 10 minutes, for it is possible that one period of an hour's duration may only show two fades, which might have occurred in the first 10 minutes of the watch. Consequently this figure 2 will occur in the total of each of the columns for 10, 30 and 60 minute periods.

Table II. shows the total number of periods observed, together with the percentage of those in which "no fades" and "fades" were recorded. From this table there does not appear to be any definite change in the percentages throughout the year excepting perhaps in the last three months. This may probably be accounted for by the fewer hours of darkness in which the B.B.C. stations were working.

It is obviously possible to represent graphically every single record received, but this has only been done in the case where any two observations have coincided in point of time. In the earlier months these coincidences were matters of chance, but during the last three months a definite programme of watches was arranged for each night. The number of such graphs which it was possible to draw on this basis as a result of each month's observations is shown in the right-hand column of Table I. It will be seen that the number is far too few to allow any but the most general conclusions to be drawn. These may be summarised as follows :—

(i) Confirmation of the fact mentioned in the early part of the paper, that no fades recorded before sunset on any B.B.C. station.

(ii) There was absolutely no similarity between any of the graphs of different observers. When two or more observers watched the same transmitter, they did not record fades at the same time, even if their receivers were situated less than a mile apart.

TABLE I.

Month.	Total No. of Periods Observed, making no Allowances.	Nos. of Observers.			Records used in this analysis.		Totals of Periods in which "No Fades" recorded.			Totals of Periods recording "Fades," with No. of Fades recorded.						Total No. of Graphs possible.
		Total No. of Obsrs. recording.	No. of Obsrs. whose records are "useless."	No. of Obsrs. whose records are always under 10′.	Total No. of Observers.	Total No. of records over 10′.	Of 10′ duration.	Of 30′ duration.	Of 60′ duration.	Up to 10′		Up to 30′		Up to 60′		
										Periods Obsd.	No. of Fades.	Periods Obsd.	No. of Fades.	Periods Obsd.	No. of Fades.	
1923																
July ..	254	42	20	9	13	38	14	3	1	24	29	2	8	1	3	2
August ..	127	29	11	7	11	25	14	1	—	11	21	3	6	1	2	2
September	209	34	12	6	16	44	27	11	4	17	36	7	23	5	17	6
October	127	24	9	4	11	38	24	9	4	14	28	6	13	5	8	4
November	249	50	8	6	36	130	69	17	11	61	151	27	121	12	63	6
December	249	48	4	2	42	146	70	29	9	76	195	37	177	19	176	18
1924																
January	254	44	6	2	36	150	84	48	20	66	169	32	144	19	151	19
February	164	29	4	4	21	53	36	13	6	17	34	3	9	2	8	11
March ..	110	24	1	3	20	75	46	11	2	29	46	11	32	3	7	6
April ..	70	17	3	4	10	36	23	9	2	13	20	4	21	—	—	0
May ..	110	20	3	1	16	75	60	26	7	15	23	10	34	2	2	8
June ..	64	12	2	4	6	32	27	14	5	5	10	4	17	3	29	2
July ..	35	11	3	1	7	25	20	14	10	5	6	3	3	3	7	3
Whole Period	2,022	118	35	9	74	867	514	205	81	353	768	149	608	75	477	87

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Comparisons were made between observers situated equi-distant from the transmitter but in different directions. Still again, on superimposing the graph of one record on that of the other, no similarity could be traced.

There are some other interesting observations bearing on the effect of the intervening country which can be made from comparison between records from different observers on the same transmitter. A remarkable example is the case of Cradiff (5 WA) observed by one amateur in the north of Wales and another in the Fen district. On comparing the results of these two records, it was found that in North Wales, Cardiff was always recorded as steady and no fading, whereas in the Fen district this station invariably showed fading. Since the two observers were approximately equidistant from Cardiff, one is forced to consider the intervening country. In the case of North Wales the signal passes over the Welsh mountain ranges, whereas its passage to the Fens is over comparatively flat country. On studying the features more closely, it is seen that the great circle from Cardiff to the Fen station passes up the mouth of the river Severn and closely follows and grazes its northern coastline and then along the river; these together may be responsible for the fades in the Fen district.

Another comparison is to be made between signals received only over land and over land and sea. For example, Holywood in Co. Down, Ulster, never recorded fading on Glasgow, the intervening distance being broken land and sea, but there is practically no "grazing" effect as the waves pass over the various coastlines almost at right angles. Also London is mostly steady at Holywood, whereas Manchester is extremely erratic, yet London and Manchester lie approximately on the same great circle through Holywood, the signal from Manchester passing mostly over sea. Many other examples could be cited, and one is led to the conclusion that fading has a great deal of "local" effect when comparing fading on the same transmitter in different districts, but that in a district itself where observers are only short distances apart, the "local" effect applies only to general behaviour, *i.e.*, a given transmitter fades or not in that district, but not instantaneously at receivers within short distances of each other.

One last remark should be made with regard to some very excellent records made in Queenstown, Co. Cork. During November and December, 1923, and January, 1924, many records were compiled on both U.S.A. and B.B.C. transmitters. The general behaviour of both was similar. Sometimes incessant and rapid fades were recorded and at other times the signals remained perfectly steady. Lengthy periods have been recorded on U.S.A. when no fades were recorded, WGY being steady for one hour at Queenstown and on another occasion, Grimsby recorded 25 minutes with no fades.

TABLE II.

Month.	Obsns. of 10′ duration.			Obsns. of 30′ duration.			Obsns. of 60′ duration.			Average No. of Fades per			Total No. of Obsns. recording
	No. of Periods.	% N.F.	% F.	No. of Periods.	% N.F.	% F.	No. of Periods.	% N.F.	% F.	10′ Obsn.	30′ Obsn.	60′ Obsn.	
1923													
July ..	38	36.8	63.2	5	60.0	40.0	2	50.0	50.0	0.763	1.6	1.5	13
August ..	25	56.0	44.0	4	25.0	75.0	1	0.0	100.0	0.84	1.5	2.0	11
September	44	61.3	38.7	18	61.0	39.0	9	44.4	55.6	0.82	1.275	1.8	16
October ..	38	63.1	36.9	15	60.0	40.0	9	44.4	55.6	0.737	0.867	0.8	11
November	130	53.2	46.8	44	38.6	61.4	23	47.8	52.2	1.16	2.75	2.74	36
December	146	48.0	52.0	66	44.0	56.0	28	32.2	67.8	1.335	2.68	6.285	42
1924													
January ..	150	56.0	44.0	80	60.0	40.0	39	51.25	48.75	1.125	1.8	3.88	36
February	53	68.0	32.0	16	81.25	18.75	8	75.0	25.0	0.642	0.562	1.0	21
March ..	75	61.4	38.6	22	50.0	50.0	5	40.0	60.0	0.613	1.45	1.4	20
April ..	36	64.0	36.0	13	69.2	30.8	2	100.0	0.0	0.556	1.615	0.0	10
May ..	75	80.0	20.0	36	72.2	27.8	9	77.8	22.2	0.307	0.945	0.2	16
June ..	32	84.4	15.6	18	77.7	22.3	8	62.5	37.5	0.313	0.945	3.625	6
July ..	25	80.0	20.0	17	82.35	17.65	13	77.0	23.0	0.24	0.1765	0.528	7
Whole Period	867	59.25	40.75	354	58.0	42.0	156	52.0	48.0	0.885	1.718	3.6	74

In conclusion thanks are due to the Radio Society of Great Britain for their assistance in introducing this investigation to the notice of their members, and to the amateurs for the time they have voluntarily given up in its pursuit.

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Rectifiers for High-Tension Supply.

Part II: Electrolytic Rectifiers.

By R. Mines, B.Sc. **[R355·5**

Theory and practice in electrolytic rectification are dealt with in this part, and some notes, both on the choice of materials and the construction of cells, are given.

Electrolytic Conduction.

THE distinguishing feature of the conduction of electricity through electrolytes is the chemical reaction that accompanies the passage of the current. Now an electrolyte is essentially a *solution* of some substance in a solvent, most commonly water; and the characteristic of a conducting solution that concerns us here is the *partial dissociation* or chemical decomposition of the dissolved substance when it is in solution. In general the molecule of the dissolved substance is split into two component parts, the "acid radicle" and the "basic radicle"; the former of these is found to possess a negative electric charge, and the latter a positive charge.

Thus when a unidirectional P.D. is applied between two electrodes dipping in such a solution (see Fig. 1), a "migration" sets in; the acid radicles tend to collect at the positive electrode, and the basic radicles at the negative electrode. On reaching the surface of the electrode each radicle is either precipitated, or reacts with the solvent or with the electrode material, depending on their chemical affinities; in doing this, its charge is delivered to the electrode, and it is the passing along of charges in this manner that constitutes the current flow in the electrolyte.

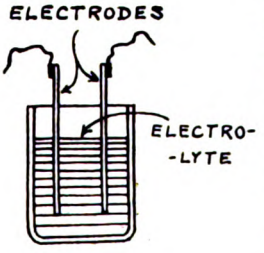

Fig. 1.

The accumulation of the products of this reaction leads to a condition of asymmetry in the cell, and gives rise to a "back E.M.F." opposing the original flow of current. Thus in the simple case of the electrolysis of impure water using platinum electrodes (or other material that is chemically inactive towards the electrolyte and the products of its decomposition), as soon as there is a sufficient layer of bubbles of Hydrogen and Oxygen adhering to the respective electrode surfaces, a back E.M.F. of about 1.7 volts comes into action, and if the P.D. applied to the cell from the external supply is less than this critical value, called the "Polarisation E.M.F.", current will practically cease to flow.

In passing it may be noted that if the supply is disconnected and the electrolytic cell is short-circuited through a galvanometer, a momentary current flows, due to the back E.M.F., in the reverse direction through the cell, which thus acts as a "gas" battery of limited capacity; the layers of bubbles disappear and the cell reverts to a symmetrical state, chemically speaking. The commercial utilisation of this principle with solid products of electrolysis is seen in the Secondary Battery—the original Planté cell consisted of two plain lead electrodes dipping in dilute sulphuric acid. Similarly if a "chemical asymmetry" is deliberately introduced into a cell by suitable choice of materials, current may be generated spontaneously on closing the external circuit, without any previous "charging"—this is the Primary Battery.

One would expect to be able to use some of these conditions of asymmetry for the purpose of rectification, since a rectifier is only an asymmetric conductor. Actually however this is not practicable; because if the electrical asymmetry of the cell is rendered independent of current flowing through it, by choosing suitable materials, it becomes, as we have seen, a battery, capable in itself of supplying the unidirectional power required. In any case, since with no known combination of materials does the back E.M.F. obtainable exceed about 2½ volts, the number of cells it would be necessary to connect in series becomes excessive for the high-tension supply even of a receiving set.

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Electrolytic Valve Action.

Nevertheless, with some combinations a true "valve action" is obtainable. Usually this occurs when one of the products of the chemical reaction is a bad conductor, and is deposited as a coherent film on one of the electrodes and partially insulates it from the electrolyte (so that the resistance of the cell increases). The P.D. applied to the cell may be increased considerably (to a hundred volts or so)—there is no definite value at which the cell will "break down."

If the P.D. is reversed, the slight leakage current (now also reversed) causes decomposition of the badly-conducting film till it disappears and the cell resumes its original conducting condition. By choosing suitable electrodes the action may be limited to one direction only of the current flow, and a cell thus constituted should act as a good rectifier; but there is this limitation, that a considerable quantity of electricity is required to form the insulating film, and with normal current density this takes a considerable time to flow. So the arrangement is of no use for our purpose after all, since usually it is required to rectify an alternating current with, for example, a frequency of a public supply.

Electrolytic Rectification.

The phenomenon described above is called "ionic" valve action, because it depends on the behaviour of the charged radicles, which are commonly called electrolytic "ions."

With certain combinations of materials, however, a phenomenon called "electronic" valve action is obtained, and we shall discover that with its aid rectification is in some cases possible at frequencies approaching a million cycles per second.

It is evident that the valve action in this case cannot be due to the insulating property of the film, since such film (whether solid or not) has to be formed and destroyed for each cycle of the alternating current. Nevertheless the presence of such a film on the anode is still necessary before rectification can take place—for a new anode, or one which has been standing idle, must always be "formed" before use. But according to the latest theory, this solid film is porous, and in the pores are formed bubbles of gas—these bubbles are next to the anode surface, the remainder of each pore being filled with electrolyte (see Fig. 2). This condition of a porous film holding gas in its pores is permanent so far as concerns the cycles of the alternating current; and it is necessary to look to some inherent

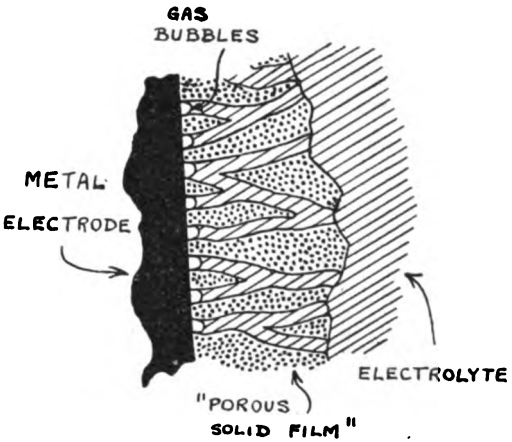

Fig. 2.

property of the combination for an explanation of the valve action.

Although the resistance of the threads of electrolyte in the pores of the film will be higher than that of the bulk of the electrolyte in the cell, it bears no comparison with that of the gas layer; in fact, the solid parts of the film and the gas bubbles together form a complete insulating jacket for the anode, and no appreciable current is able to pass through the cell with normal P.Ds. Note however that this insulating jacket (the effective thickness of which may be under a millionth of a millimetre) takes practically the whole potential drop; and if this is raised too far, the potential gradient becomes such that the gas exhibits first a glow discharge, then a spark discharge (sparks can be seen at the electrode surface of a rectifier cell that is being operated near its limit of P.D.), and finally its resistance breaks down in known manner.

On the face of it one would have expected that (subject to this P.D. limitation) the gas layer would preserve the insulation of the electrode with the P.D. in either direction. But here we must anticipate a little our consideration of gaseous conduction, and

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take into account the fact that it is an asymmetric process, unlike conduction through an electrolyte described above. As with an electrolyte, both positively-charged and negatively-charged, carriers may take part in the conduction process; but with a gas it is not necessary for an exact balance to exist between the numbers of the two kinds of carriers; and further, the negative carriers may be, (and in fact most commonly are,) plain electrons, whereas the positive ones are of necessity particles of matter of some kind or other. Therefore, in the case of a thin film of gas, conduction will take place quite readily if electrons are available, if their "mean free path" is greater than the film thickness. On the other hand, if positive carriers only are available the conduction cannot take place so readily—a very much greater force is required to make them traverse the gas film, since though they carry only the same charge (in magnitude) they have a mass thousands of times as great as the electrons. The effect of this asymmetry is that such a film "breaks down" to the passage of electrons very much more readily than to the passage of material carriers.

In the particular case of an electrolytic valve, the gas film is bounded by electrolyte on one side of it and by a metal electrode on the other. The electrolyte can offer only charged "radicles," *i.e.*, particles of matter; whereas the metal, being a conductor of electricity, contains free electrons. When an E.M.F. is applied to the cell in the correct direction (making this electrode *anode*) some of these electrons will traverse the film; thus the cell conducts current: but with the P.D. in the reverse direction, as long as it is below the critical value, "nothing happens," because there is not force enough available to drive any appreciable number of heavy material particles across the film.

This explanation of the action is supported by the following experiment: if a metal plate is brought up quite close to the active electrode and held there by an insulating handle, the cell resistance falls, rectification ceases, and sparks pass between the plate and the electrode. In effect the plate makes available a supply of electrons on the second side of the gas film.

Practical Application.

One of the most important factors in the choice of a suitable electrolyte is its sensitivity to temperature. Primarily, both it and the electrode material should be chosen so that the solid film formed shall not be decomposed under a reasonable rise of temperature. The condition is helped by choosing an electrolyte which keeps sufficiently cool—but it is not necessarily best to use the most *efficient* electrolyte, *i.e.*, one which will have minimum losses at the commencement of a run; for it may have a positive temperature coefficient, and this means that any rise in temperature that occurs causes an increase in the resistance, and hence in the heat generated in the cell. It is easily possible for the rate of heat generation to increase faster with temperature than the rate at which heat can escape from the cell; under these conditions the temperature is unstable, and rises rapidly until the rectifying property of the cell is destroyed.

Much labour has been expended in determining what materials will support the rectifying action and at the same time will maintain satisfactory operation over a period of time. Among others *Codd*[1] gives some interesting results; so also does *Nodon*.[2] Modern practice shows that *Ammonium Phosphate* (a strong aqueous solution) is favoured above others by many experimenters; *Sulphuric Acid* (dilute) is also being used in some commercial rectifiers.

The acid electrolytes have the higher conductivity and so give rise to less heating than the others, which is a useful advantage; but in general the breakdown P.D. of the cell is lower, necessitating a larger number of cells for a given supply P.D.

For the electrodes the choice of suitable material seems to have been made more readily. The active electrode must be one that yields the required porous film under the electrolytic action; and as already stated, the film should be stable under rising temperature.

Aluminium fulfils these conditions—it oxidises readily even in ordinary air, and the oxide forms a tenacious film; its compounds usually require a high temperature for their decomposition. Further, it is cheap

[1] *Elec. Review*. Vol. 93, p. 324, 2nd Mar., 1923.
[2] See Jolley's *Alternating Current Rectification*, p. 301.

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and easy to work, and is easily procurable in forms to fit any type or rectifier cell. It has in fact become the most popular material with the radio experimenter.

E. H. Robinson,[3] who has done useful pioneer work in adapting this kind of rectifier for high-tension supplies, used aluminium and worked it at a current density of about 5mA/cm.^{2} [4] (for a 50 cycle supply). Thus a strip 1 cm. wide and with 5 cm. of its length immersed in the electrolyte (ammonium phosphate was used) the total area is 10 cm.^{2} and the cell will deliver about 50mA of rectified current.

This combination has the further advantage of withstanding a high back P.D.—when in good condition 120 to 140 volts may be allowed for each cell; thus for a D.C. output of 1 000 volts, 10 cells were connected in series to form each "rectifier group," giving a substantial margin for deterioration of the cells.

Tantalum is being used by an American firm in the "Balkite" Battery Charger.[5] Here the electrolyte is sulphuric acid as used in accumulators. The current density of the active electrode (which is a thin sheet) is 0.5 amp/cm.^{2}—a hundred times as great as the figure mentioned above for aluminium. The high cost of the electrode metal does not therefore weigh so much because of the small size required. This combination is not, however, suitable for high-tension supplies because the maximum back P.D. allowable across the cell is only 27 volts.

Tungsten has been tried successfully by L. H. Walter[6] as an anode with different electrolytes. In one cell the tungsten filament from a 60-watt lamp and a lead cathode were immersed in sulphuric acid (sp. gr. 1.2); a rectified current of 0.5 amp was obtained, giving a current density of about 4 amp/cm.^{2}, which is eight times the value quoted for tantalum.

It has also been proposed recently[7] to use a colloidal suspension for one or both of the electrodes of an electrolytic rectifier, a porous membrane being used to separate the colloid from the electrolyte. Judging, however, from some experiments published in a French radio journal on their use of colloids for wireless detection and amplification (using immersed electrodes analogous to those of the thermionic valve), it would appear that such a colloid would not be sufficiently stable under the influence of an electrostatic field.

The *inactive electrode* is primarily a means of making electrical connection to the electrolyte, and for this function to be unimpaired there should be no chemical action between the two when the cell is working (or when idle). *Iron* and *Graphite* have been frequently used, but *Lead* has been found the most convenient for experimental work.

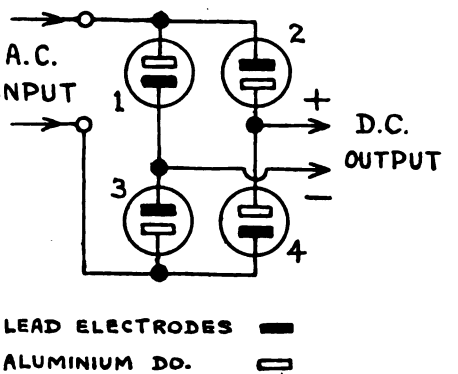

Fig. 3.

Rectifier Circuits.

We have seen that the fundamental form of chemical rectifier cell has two electrodes constituting its two poles, each having a terminal for connection to the external circuit; no "auxiliary supplies" are required, as, for example, there are with a valve. Thus in the rectification circuits given in a previous article[8] the cell may be connected directly in circuit at the points marked R_1, R_2, etc.

In some instances, however, a simplification is possible, in so far as two units may be combined into one. This is done by putting the four electrodes (belonging to the two cells) in one pot, with the same electrolyte; then the two of like kind which are normally connected together externally are replaced by a single one. Obviously it is not possible to combine into one electrode two of a different kind, since their functions are different. Thus in Fig. 3,

[3] E.W. & W.E., Vol. I., p. 154, December, 1923.
[4] This figure appears rather low.
[5] Described in E.W. & W.E., p. 429, April, 1925. See also Abridgment of Patent No. 235 658 in *Patents Journal* of 12th August, 1925.
[6] *J.I.E.E.*, Vol. 43, p. 547, 1909.
[7] See Abridgment No. 224 871, *Patents Journal*, 14th January, 1925.
[8] E.W. & W.E., Vol. I., p. 580, July, 1924.

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it is impossible to combine the pairs of cells R_1 and R_2, or the pair R_3 and R_4.

There is also a second limitation, as to which kind of electrode may be made common. For it must be remembered that in such a combination cell there are three electrodes, one of one kind, and two of the

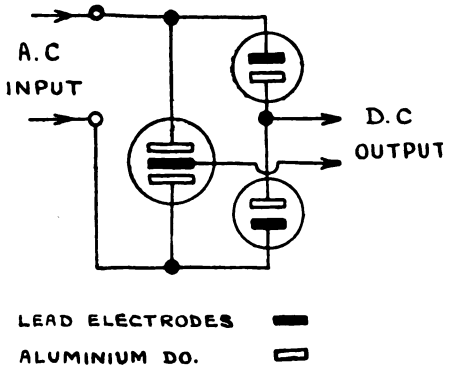

Fig. 4.

other kind. If, for example, two lead electrodes and one aluminium one were used (*e.g.*, replacing the pair of cells R_2 and R_4 in Fig. 3), the immediate result would be a short-circuit of the alternating supply, since the lead electrodes, whose sole function is to make connection with the electrolyte, are in effect connected together. It is possible, however, to use two aluminium electrodes with a common lead one (*e.g.*, replacing the pair R_1 and R_3 in Fig. 3), because when these are formed as described above they are capable of withstanding the full P.D. in one direction; and since they are connected to opposite poles of the alternating supply, with the potential of the electrolyte at an intermediate value, only one of them at a time will be passing current. The rectifier action is thus preserved. (See Fig. 4.)

Similarly when a two- or three-phase supply is being used, it is possible to use a single cell for all the phases, provided the connections are such as to require a separate aluminium electrode for each phase and a common lead one.

The Capacity Effect.

When in action, the active electrode is insulated from the electrolyte by a composite layer; the total thickness of this depends mainly upon the time the rectifier has been in use and the P.D. applied to it —it may reach a millionth of a millimetre. But the "effective thickness of insulation" is the spacing between electrode surface and electrolyte maintained by the gas in the film; and this is a much smaller quantity.

Hence even though we assume that the "gas film" has unity dielectric constant, the two conductors (electrode and electrolyte) in such close proximity from a condenser with a very high capacity relative to the area of its plates; in fact, capacities of over 100μF. per square centimetre may be attained.

This property has been used for some time past in the "electrolytic condenser"; one of these units of 30μF. occupies about the same space as a 2μF. paper condenser. The device may be used as a reservoir condenser on a single rectifier circuit (see Fig. 5), where the output P.D. does not exceed the safe limit for a single cell. Here the D.C. output P.D. supplies the unidirectional polarising P.D. which is necessary to keep the condenser electrodes "formed."

Obviously when arranged as shown the two cells may be coalesced into a single one with a common lead cathode, in the manner stated above. This arrangement (as devised by Messrs. Siemens for battery charging) is shown in Fig. 6. To provide an adequate value of the smoothing capacity the "condenser" electrode is made up to sixteen times the area of the "rectifier" electrode.

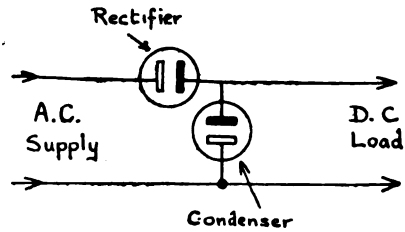

Fig. 5. *Use of Electrolytic Condenser.*

Use of Higher Frequencies.

The effect of this capacity on the rectifier is that a heavy charging current is taken when the applied P.D. passes zero and builds up in the direction for which the cell is an insulator. Similarly when the P.D. falls from its maximum value to zero again a corresponding discharge current flows (this is followed during the remaining half cycle by the load current in the same direction but containing no capacity current). The

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charging current wave is thus far from being a "sine wave leading by 90° on the P.D. wave"; but it is seen to contain such a wave as its fundamental component, and its effect is similar to that of a condenser connected across the rectifier cell.

If a rectifier normally designed for a power frequency is used on a supply of, say, 10 times the frequency, it will take a capacity current 10 times as great. This will in many cases be equivalent to a short-circuit on the alternator or transformer supplying the power, and obviously no rectified output will be obtainable. The first consideration, then, in endeavouring to work on higher frequencies is to reduce this capacity effect; this can be done only by reducing appropriately the area of the active electrode exposed to the electrolyte. This point and other considerations have been dealt with by E. H. Robinson.[9]

It must be borne in mind also that to use a *smaller cell* is not sufficient, for probably the losses will be a larger proportion of the input at the higher frequencies, and the cell must be capable of dissipating these as heat without too great a rise in temperature. Actually, the higher the frequency, the higher is the current density that must be used on the active electrode.

[9] E.W. & W.E., Vol. I., p. 672, August, 1924.

Robinson (*loc. cit.*) uses a current density of 0.25 amp/cm.^{2} at 500 cycles, being 50 times his value for 50 cycles, with aluminium

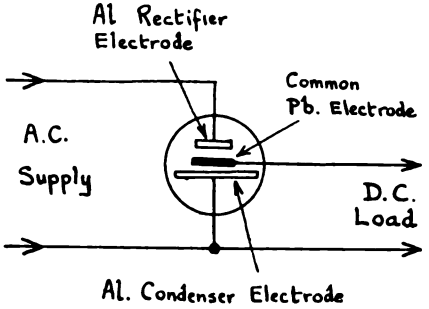


Fig. 6. *Messrs. Siemens' Connection.*

electrode. Thus with electrodes of tantalum or tungsten it will be increasingly difficult to produce a satisfactory high-frequency rectifier.

An alternative method of reducing the capacity effect that has been proposed is to use the electrolytic salt in a molten state instead of in aqueous solution; with fused potassium nitrate, rectification has been successfully accomplished at a frequency of 300 000 cycles per second.[10]

[10] See also Correspondence in E.W. & W.E., Vol. I., p. 746, September, 1924.

A Variable Coupling Unit.

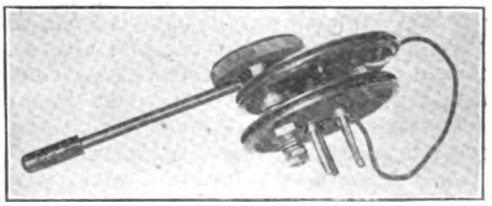
A VARIABLE coupling sent us recently by Midland Radiotelephone Manufacturers, Ltd., Brettell Lane Works, Stourbridge, has been designed to take the place of plug-in anode and reaction coils.

Our photograph shows the construction of the unit, and it will be seen that the two coils are wound between circular ebonite discs. The under disc of the fixed coil is fitted with four split pins arranged to fit into an ordinary valve-holder. The second coil is capable of rotation about a pivot which is screwed through the fixed coil. The ends of the two coils are connected to the four pins. Control is obtained either by the knob shown or by an extension handle.

The finish is exceptional; all the brass parts are well lacquered, and the ebonite is highly polished.

We measured the inductances of the coils of the unit sent us (range: 250-650 metres) and found the fixed coil to have an inductance of 209μH. That of the moving coil was 199μH.

These results show that the coils of the unit correspond approximately to standard plug-in coils of 75 turns. The maximum coupling coefficient was found to be 28 per cent. The minimum was very low, but never became negative.



The Mellowtone Reaction Unit.

The component is made in four sizes, to cover four wave-length bands, with a reasonable overlap: 80-250, 256-650, 600-1 650 and 1 500-3 000 metres, priced at 5s. 6d., 5s. 6d., 7s. 6d. and 10s. 6d. respectively.

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For the Esperantists.

A GLIMPSE AT ESPERANTO.

The Alphabet.

A B C Ĉ D E F G Ĝ H Ĥ I J Ĵ K L M N O P R S Ŝ T U Ŭ V Z.

No Q, W, X, or Y.

Pronunciation.

The Vowels: **A** (bah) **E** (there) **I** (pier) **O** (pore) **U** (poor)

The **Consonants** sound as in English, except **C** like **ts** in **bits**, *e.g.*, **caro** like *tsaro*; **acido** like ah-tsee'-doh. **Ĉ** like **ch** in **church**. **G** like **g** in **go**. **Ĝ** like **g** in **gem**. **J** like **y** in **yes**, *e.g.*, **jaro** like *yaro*; **bojo** like *boyo*. **Ĵ** like **z** in **azure**. **S** like **s** in **so**. **Ŝ** like **sh** in **show**. **H** (guttural, very seldom used) like **ch** in **loch**.

AJ, OJ, as in **my boy**. **EJ,** as in **obey**. **UJ,** as in **hallelujah**. **Ŭ** is the Esperanto **W,** as in **well, how**; **AŬ** as **ow** in **cow**. **EŬ,** as in **they—were**.

Accent always on the second last syllable. Phonetic spelling. **-O** is the ending of the **NOUN**. **ADJECTIVES** end in **-A**.

Nouns and adjectives form the **PLURAL** by adding **-J**.

The simple **VERB** endings:—

Infinitive.	Present.	Past.	Future.	Conditional.	Imperative.
I	**AS**	**IS**	**OS**	**US**	**U**

N marks the **ACCUSATIVE** (direct object). **ADVERBS** end in **E**. **NO IRREGULARITIES.** **NO EXCEPTIONS.**

Distordado. [R800

Serio de artikoloj verkitaj de teknika spertulo por montri la kaŭzon de la nebona tonkvalito de nuntempaj aparatoj, kaj kiumaniere oni povas ĝin eviti.

PARTO II.

KIEL UZI LA LASTAN VALVON.

La antaŭa parto pritraktis nur unu punkton, la neceson utiligi valvon kapablan porti sufiĉan potencon. Ni montris, ke la malfacileco okazas nur je la lasta ŝtupo de aparato por hejma laŭtparolila funkciado, kaj ni faris komentarion pri nuntempaj valvoj taŭgaj por tiu ĉi celo.

En la nuna parto ni intencas doni konsilojn pri la *uzado* de la valvo.

Ni jam diris, ke la unua estas valvo, kies karakterizo estas rektà trans amplekso de kradtensio almenaŭ egala al tiu de la "svingiĝo" naskita de la envenanta signalo, t.e., ĉirkaŭ 15 voltoj por la lasta valvo en aparato, kiu emisias bonan laŭtparolilan fortecon en mezgranda ĉambro. Ne malfacile estus pruvi tiun ĉi neceson, sed por ŝpari tempon ni denove diros, ke ja estas necese funkciigi je la "rekta" parto de la kurvo se ni deziras eviti distordon.

La longeco de la "rekta" parto varias laŭ la filamenta tensio, kiel oni vidas per Fig. 1. Tial, la unua konsilo al la uzanto estas:—

SUFIĈE VARMIGU LA FILAMENTON.

Jen kelkeda proponitaj tensioj minimumaj por diversaj tipoj, kalkulante 15-voltan svingiĝon. Ili estas, komprenoble, nur proksimumaj. Poste ni montros kiel fari definitivan indikon:—

Tipo.	Taksitaj Voltoj.	Minimumaj Voltoj.
L.S.5	4.5	3.25
625	5.5 – 6	5
435	4	3.5
606	6	5.5
312	3	3
240	1.8 – 2	2

Due, supozante ke la "rekta" parto estas sufiĉe longa, estas alia punkto. Eĉ je la momento, kiam ĝi estas plej pozitiva, la krado devas ĉiam esti negativa rilate al la filamento. Ni klarigu alimaniere; se estas svingiĝo 15-volta, kaj estas konstante – 5 voltoj ĉe la krado, tial la svingiĝo estos de – 12½ voltoj ĝis + 2½ voltoj, sed tio estas malĝusta. Ni devus plialtigi la kradtension ĝis almenaŭ 7½ voltoj, kiam la svingiĝo devos esti de – 15 ĝis 0. Estas efektive pli sendanĝere uzi 8 aŭ 9 voltan kradtension, tiel ke la plej pozitiva loko de la svingiĝo estos – 1 aŭ – 2 voltoj. Sekve de tio, ni recevas nian duan konsilon:—

ĈIAM UZU KRADTENSION DE PLI OL DUONO DE LA SVINGIĜO.

Oni notas, ke unu, aŭ eble du piloj, sufiĉos por ĉiu escepte la lasta valvo, por hejma funkciado.

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LA NECESO POR MILIAMPERMETRO.

La lasta punkto decidota estas pri la altatensia voltkvanto; tion jam fiksis definitive la antaŭaj konsideraĵoj. Konsiderante, ekzemple, la kurvon CD de Fig. 2, estas bone sciite, ke la efekto de ŝanĝo de la a.t. voltkvanto estas fari kurvon samformatan sed movitan dekstren aŭ maldekstren, kiel, ekzemple, la punktita kurvo por 200 voltoj. Se ni deziras kaŭzi la kradon svingiĝi de C ĝis D, t.e., 22-volta svingiĝo, oni povas facile vidi, ke la *konstanta* krada tensio devas interrespondi kun punkto mezvoje inter ili, t.e., la punkto G. Tie ĉi la kurento estas 14 miliamperoj, kaj tial ni devas nur almeti variantajn anodtensiojn ĝis, kun la kradtensio je 12 voltoj, la anoda kurento estas 14 miliamperoj.

Ĉe tiu ĉi valvo kaj filamenta varmeco, nia norma svingiĝo de 15 voltoj varias de C ĝis H (−22 ĝis −7). La interrespondanta meza punkto estas K, 11 miliamperoj, kaj tio estas havigenda per 8 voltoj kradaj La voltkvanton altatensian bezonatan ne montras la kurvo, sed ĝi estas proksimume 190.

Kaj jen, nunokaze, niaj legantoj certe ekkrios pro konsterno aŭ eĉ moko. "Ho ne, tute senutile! Ni ne havas miliampermetron, kaj iuokaze la fabrikistoj ordonas, 'Uzu 100 voltojn,' kaj ni havas nur unu baterion."

Al tio ni respondas, "Se vi *ja* posedus miliampermetron, vi baldaŭ uzus 190 voltojn, kaj tiam vi eble ĝuus bonan ricevadon." La miliampermetro senpere anoncas, ĉu ekzistas distordo pro la valvoj.

Jen la kialo. Se la valvoj ne funkcias ĉe la rekta parto de siaj kurvoj, ili, plimalpli, rektifos. Tio signifas, ke pligrandiĝo ĉe la malaltfrekvenca enmeto produktos definitivan ŝanĝon de la kontinukurenta anoda kurento, kaj la miliampermetro, kiu estas kontinukurenta instrumento, ekmoviĝos je ĉiu laŭta tono. Se ne ekzistas distordo valva ĝi restos tute konstanta.

Oni rimarku, ke la metro ne devas esti absolute preciza—ne gravas se ĝi montras 8 miliamperojn kiam estas nur 7.5; ĉar ĝia ĉefa funkcio estas proksimume indiki la kurenton fluantan, kaj samtempe, per ekmoviĝo, montri ian *ŝanĝon*.

Tia metro estas aĉetabla je tre malkara prezo, kaj devus esti enkorpigita en ĉiun bonkvalitan aparaton laŭtparolilan. Per ioma manipulo, oni povas aranĝi, ke ĝi indiku ankaŭ la filamentajn tensiojn kiam bezonataj, tiel ke la uzanto faris ĉion necesan por liberigi sian aparaton kontraŭ valva distordo.

FUNKCIADO SEN KURVO.

Ĝi estas ankaŭ uzebla por "elekti" valvtensiojn sen kurvo karakteriza laŭjene: Funkciigu la aparaton kun la metro enmetita en unu aŭ alia altatensia konduktoro, kaj kun la ĝusta kradtensio ĉe la valvo. Alkonduku la taksitan filamentan tension, kaj observu la metron dum vi atingas la elmetan fortecon bezonatan, la alta tensio estante, ekzemple, 120 voltoj. Se ĉiu laŭta signalo *pligrandigas* la altatensian kurenton, altigadu la altatensiajn voltojn ĝis tio jam ne okazas. Se vi troŝarĝas, ĉiu laŭta signalo *malpli-*

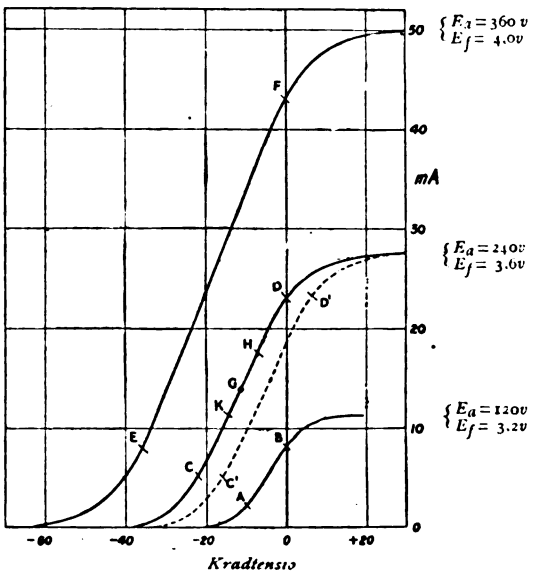

Fig. 1.

grandigos. Se, je unu kvanto de alta tensio, la montrilo vibras nedifinite, jen pligrandigante, jen malpli-grandigante, tio estas signo, ke la filamenta varmeco ne ŝufiĉas. Oni ĝin plivarmigu, kaj faru novan provon. Se ne estas eble aranĝi, ke la montrilo restu konstanta, kun la plena taksita tensio ĉe la filamento, uzu pli potencan valvon.

Efektive, por praktika uzado, ne ĉiam estas absolute necese, ke la metro restadu precize konstanta. Oni devas memori, ke la inĝenieroj ĉe senda stacio ŝanĝas la modulon, por ke ĝi tenu sufiĉe bonan fortecon aŭ por parolado aŭ por granda orkestro. Estas tamen diversaj subitaj

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bruoj, kiel ekzemple, la bato de tamburo—kiuj kreas tre grandan svingiĝon, kaj per transformatore-kuplita amplifikatoro, oni povas permesi, ke tiaj bruoj estu iomete distorditaj, sen grava perdo de kvalito. Ankaŭ, la metodo aludita permesas, ke oni vidu distordon plibone ol ĝin aŭdi. Oni trovos, ke malmulta ekmovigo de la montrilo indikos distordon ne rimarkitan de la ordinara orelo.

Se oni insistus, ke eĉ la plej laŭta malofta sono ne ekmovigu la montrilon, oni devus kalkuli por svingiĝo, de ĉirkaŭ 30 ĝis 40 voltoj, kiu bezonus tre grandajn kradtension, altan tension, kaj anodan kurenton.

La verkanto trovas, ordinare, ke kradtensio de 6 ĝis 8 voltoj, kun 120-150 voltoj altatensiaj, kaj anoda kurento de 5-7 milamperoj ĉe la lasta valvo, funkcias tute bone ĉe la plimulto de la altpotencaj valvoj cititaj. Estas ja videbla ekmoviĝo de la metra montrilo okaze de laŭta muziko, sed la distordo estas nerimarkebla al iu ajn, escepte treege lerta muzika kritikisto; kaj la plimalaltaj tensioj kaj anodaj kurentoj nature multe ŝparas altatensiajn bateriojn. Sed oni ne tro kompromisu.

FINO.

Estas kaŭzoj kial ŝoke- aŭ rezistance-kuplitaj amplifikatoroj estas pli sensitivaj tiurilate, kaj oni devas tre zorgi pri ili. Punkto citinda pri tio, estas, ke la altatensiaj voltkvantoj pritraktitaj en ĉi tiu artikolo estas tiuj, *ĉe la valvo mem.* Se estas rezistanco en la anoda cirkvito, la *bateria* tensio devas esti pligrandigita. Tio ne koncernos nin, se ni juĝos per la anoda kurento montrita de la metro, nur altigante la voltojn bateriajn ĝis la kurento estas ĝusta.

Resumi—Por eviti distordon pro la valvoj—

1. Uzu valvon kun sufiĉa elmeta povo: por hejma funkciado en tre granda ĉambro; L.S.5; granda ĉambro, tipon 625 aŭ 435; mezgranda ĉambro, tipon 606 aŭ 312; malgranda ĉambro, tipon 245. Oni povas uzi ian tipon por ĉambro *plimalgranda* ol tiu, por kiu ĝi estas rekomendita. Tio estas por la lasta ŝtupo. Por antaŭaj ŝtupoj, uzu ian ajn valvon,

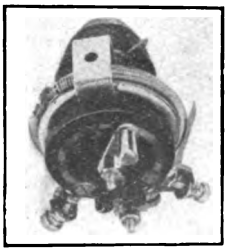
2. Donu al la lasta valvo kradtension plimalpli laŭjene: Tre granda ĉambro, 20 voltoj; granda ĉambro, 10 voltoj; mezgranda ĉambro, 6 ĝis 8 voltoj; malgranda ĉambro, 4 ĝis 6 voltoj. Kompreneble tiuj tensioj estas nur proksimumaj; oni devus kontroli ilin per provoj. La antaŭaj valvoj ordinare ne bezonos pli ol 1½ aŭ 3 voltojn.

3. *Enmetu miliampermetron en la anodan cirkviton,* kaj alĝustigu la altan tension ĝis oni vidos nenian ekmoviĝon ĉe la metro dum laŭtaj sonoj. Tio kredeble bezonos treege plimulte de alta tensio ol ordinare uzata, sed ne timu. La rezulto meritos ĝin.

La ĉi-supraj instrukcioj bone pritraktas tion, kio, laŭ la opinio de la verkanto, estas la plej ofta kaŭzo de distordo ĉe hodiaŭaj aparatoj—la tipo de valvo uzenda, kaj kiel ĝin uzi.

A Novel Combined Rheostat and Potentiometer.

THE Igranic Electric Co., Ltd., of 149, Queen Victoria Street, E.C., have recently produced some novel components, including their standard filament rheostats, combined with either a standard 300 ohm potentiometer, a high resistance potentiometer (30 000O), or a variable grid leak (0-5 MO). The low resistance rheostat is of the usual wire-wound type, while both the H.R. potentiometer and the grid leak are of the graphite type.



The Igranic component described herewith.

A base of moulded material is provided with a circular, raised portion, over which a graphite rod, mounted as a spring plunger, rotates. Thus it not only makes contact, but replenishes the supply of graphite on the raised portion, which forms the resistance element. In the case of the grid leak, the raised portion of the moulded base is smooth, but that of the potentiometer is made with a number of concentric circular grooves, which hold more graphite, and thus give a lower resistance than in the case of the grid leak.

In each case the two resistances are controlled by two concentric knobs. The components are fitted with the requisite terminals, one being common in each case.

These components are very neat in construction, and take up no more room on the panel than does the filament rheostat alone.

The prices are: rheostat and low resistance potentiometer, 9s.; rheostat and H. R. potentiometer, 8s.; rheostat and grid leak, 8s.; The rheostat can be supplied with resistances of 4, 6, 8 or 10 ohms.

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Letters of interest to experimenters are always welcome. In publishing such communications the Editors do not necessarily endorse any technical or general statements which they may contain.

Proposed Institute of Radio Engineers.

The Editor, E.W. & W.E.

SIR,—I think it has been quite clear in all the correspondence that the above Society was proposed because there did not appear to be any body in existence in this country which catered sufficiently for the growing number of wireless engineers.

I am very pleased to say that by invitation of the Committee of the Wireless Section of the Institution of Electrical Engineers, I was present at a meeting of the Committee which took place on Friday, 24th July. Matters were discussed very fully and I must thank the Committee for the businesslike manner in which they dealt with the subject. For the present it is sufficient for me to state that I am satisfied that entrance into the I.E.E. by those professionally engaged in wireless matters is not as difficult as I had imagined, and that it is realised by the Institution that radio matters are of great and growing importance.

I would like all those who have written supporting the proposed Society to feel that they have done a great deal of good in demonstrating the need of more activity in wireless matters.

Further criticisms on the position after perusing any statement the Council of the I.E.E. may make in the Technical Press can be sent to Mr. Y. W. P. Evans, 66, Oxford Road, Manchester. All our friends may rest assured that their interests will be well looked after.

J. NELSON.

7, High Street,
Prescot.

The Editor, E.W. & W.E.

SIR,—You will probably have read an announcement in the electrical journals to the effect that the question of a new Wireless Society was discussed at a recent Committee meeting of the I.E.E., at which Mr. Nelson was present by invitation. The statement goes on to say that "The definite conclusion has been arrived at that there is no need for a new body." As Hon. Secretary of the proposed Association I have been asked to state that the definite conclusion arrived at is only definite in so far that it should be augmented by the words "should it be proved conclusively that the Radio Engineering Section of this country is fully catered for by the Wireless Section of the I.E.E."

I am to add that before this can be proved, the statement which is shortly being issued by the Committee of the I.E.E. will have to be studied and commented upon by those engaged in the Radio profession.

Y. W. P. EVANS,
Hon. Sec. Temp. Proposed Radio Institute.

66, Oxford Road,
Manchester.

Strength of Atmospherics.

The Editor, E.W. & W.E.

SIR,—The following account of some rough measurements taken of the strength of atmospherics at different wave-lengths may be of interest.

The receiver used for these tests was an aperiodic aerial arrangement with two L.F. valves of the D.E.5 type. A V.24 was used in the detector side, and 60 volts H.T. was put on all valves. A Silvertown galvanometer with a 90° scale was connected in series with a pair of 2 000 ohm phones, and when no signals or atmospherics were being received the needle stood at zero. During the tests, a thunderstorm was going on, about ten miles away, and on listening on 400 metres with the set just on the oscillating point, static was so strong that at times the needle flicked round to 90° (full scale) and remained most of the time between 70° and 90°. We will say this wave-length gave an average reading of 80°.

Next the set was tuned to 200 metres, where a marked decrease in atmospherics was at once noticed. Here the needle read 30° as an average, while at 120 metres 20° was the average reading. Forty metres was the next wave-length measured, and here the needle stood at 10° most of the time, and never flickered above 15°. Again, on 20 metres, only a very slight movement of the needle occurred, about 5° at the most, while at 15 metres atmospherics were practically nil, making only a slight sound in the 'phones, and the needle stood at zero.

A return was then made to 400 metres and the whole process gone through again in order to check the former readings. Although these measurements are only rough they serve to show how immune the lower waves are from the greatest enemy of wireless —static.

One other interesting point: some few weeks ago I was working G.2MX on a Sunday night, atmospherics at this end being nil, not even a distant crash was heard. Greatly to my surprise 2MX asked for a report, and reported static as "terrific" at his end! Considering the distance between 2MX and myself is only about 35 miles, air-line, I

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think the above is very strange. That static conditions can be local is something new to me, for some text books tell us that a lot of the Xs we hear originate in Africa !

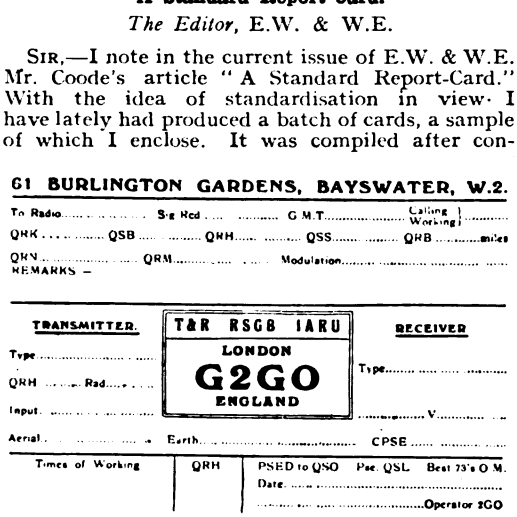
F. WALKER.
(5 AX).

Crowmarsh,
Wallingford.

A Standard Report-Card.

The Editor, E.W. & W.E.

SIR,—I note in the current issue of E.W. & W.E. Mr. Coode's article "A Standard Report-Card." With the idea of standardisation in view I have lately had produced a batch of cards, a sample of which I enclose. It was compiled after con-


61 BURLINGTON GARDENS, BAYSWATER, W.2.

To Radio..... Sig Rcd ..... G.M.T..... Calling / Working .....
QRK ..... QSB ..... QRH..... QSS..... QRB ..... miles
QRN ..... QRM..... Modulation.....
REMARKS –

TRANSMITTER. | T&R RSGB IARU | RECEIVER
Type..... | LONDON | Type.....
QRH ..... Rad..... | G2GO | .....
Input..... | ENGLAND | .....V.....
Aerial..... Earth..... CPSE.....

Times of Working | QRH | PSED to QSO Pse. QSL Best 73's O.M.
Date.....
.....Operator 2GO

The specimen standard card referred to below.

sultation with several brother amateurs, and produced in its present form as most nearly filling the requirements of a standard card.

The production price, as matters now stand, is, of course, comparatively high, but if the cards were produced in large quantities, they would, I think, work out very cheaply.

The ideal aimed at was to produce a card which not only would furnish the receiver with all the information necessary, without being overloaded, but also in layout and colour would be sufficiently distinctive to differentiate it from advertisement cards, order cards, etc.

Moreover the card would lend itself well to index, a means of reference I see Mr. Coode suggests.

The idea of duplicate report-cards has the disadvantage, I think, of involving the use of blue leaf on the card to be sent. Everyone knows how difficult this usually is to read.

If, with your kind help, I could get some idea of how this card meets the requirements of the amateur fraternity as a whole, I should be very pleased.

I hope Mr. Coode will forgive me criticising his layout in general, but I think that popular feeling would be for something more distinctive.

I have enclosed a standard specimen card and also a blank card ready for blocking in.

E. H. APPLEBY (Member T. & R. Section).
The Croft,
Wimbledon, N.W.10.

The Editor, E.W. & W.E.

SIR,—With reference to Mr. M. T. Coode's article on "A Standard Report-Card" in last month's issue of E.W. & W.E. I wish to correct one or two points and to offer criticism.

In the first place it is stated that there exists in America a standard report-card. Although I have received over 700 cards from America I can find only four cases where the design of the card is used by another station, and these four designs are entirely different. The greatest number of cards I have of one design is three. This is the nearest approach to a standard I have seen. Individuality in report-cards will always exist, but there are certain generalisations that have been made. For instance, how often do we see a card of the vertical type ? I received ten of them in two years !

The horizontal type may be set out in a much neater fashion. Instead of the report on the transmission given in Mr. Coode's card : signal strength ——λ——.——fading, QRM——,——X's ; on two lines—we may have QRK——QRH——QSB——QSS——QRM——QRN——on one line ; another line for a description of the receiver, one for the aerial, one for the counterpoise, and one, or perhaps two, for a list of the best DX stations logged, in order that the transmitter to whom the card is sent may form an idea of the efficiency of the receiver. In conclusion we have two lines for remarks.

S. K. LEWER (6LJ).

32, Gascony Avenue,
West Hampstead,
London, N.W.6.

The Editor, E.W. & W.E.

SIR,—With reference to the article, "A Standard Report-Card" by M. T. Coode, I have a suggestion to make on the subject of transmissions and the identification of reports thereon.

It is that the particulars of transmissions be recorded in a book having numbered pages, a separate page being used for each transmission, which would take, as a reference, the number of the page on which it was recorded. The number would be signalled (*e.g.*, "Test No. 10") and reports asked for on that particular test. Reports when received could at once be associated with their respective transmissions, and clock uncertainties avoided.

It is thought that this would particularly assist stations having foreign range ; time and date calculations being ruled out.

H. BISHOP (6QS).

56, Upper Valley Road,
Sheffield.

The Editor, E.W. & W.E.

SIR,—As a non-transmitter I have read your article on Standard Report-Cards with much interest. I have three suggestions to offer, viz. :—

(*a*) "Calling" to be bracketed with "working" (an obvious difference).

(*b*) G.M.T. to be bracketed with B.S.T. (British Summer Time) and

(*c*) The inclusion of QRH.

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I think the inclusion of QRB is quite good and if a standard report-card could be published it would lead certainly to a much greater number of reports being recorded.

H. PORTEOUS KING.

107, Elgin Road,
Seven Kings, Essex.

Methods of Coupling.

The Editor, E.W. & W.E.

SIR,—It has been common practice since the "low-loss" tuner came into being to use a one-turn coil in the aerial circuit loosely coupled to the secondary circuit to put the received voltage variations on the grid. This system works extremely well on the wave-band of about 80-120 metres simply because the aerial circuit was then tuned to a wave in or near this band, and the transference of energy to the secondary coil tuned to any wave in that region was perfectly satisfactory.

Now, if the aerial circuit is allowed to remain like this while the secondary is tuned to a much lower wave, say 40 or 20 metres, the signals on these lower waves are weak. This is because the aerial circuit is tuned to a wave much higher than the working wave, and there is little transference of energy. To reduce the wave-length of the aerial circuit we may, of course, introduce a small series condenser. This is fairly satisfactory, but much better signals may be obtained with the grid circuit. The aerial is simply tapped on to the grid coil a few turns above the filament lead, which is earthed, while the grid lead (from the condenser) is tapped on higher up. The position of the grid tap determines the wave-length, and the position of the aerial tap determines the coupling. The number of turns in the aerial portion is about a quarter of the number of grid turns for all waves.

At my station, by changing from the one-turn aerial coil to the grid-tap circuit, the strength of signals on the low waves (below 50 metres) was increased enormously. It is now possible for me to cut out the L.F. amplifier and hear just as many stations as with the one-turn aerial coil and the amplifier. The tuning of the grid-tap circuit is quite as simple as the old method.

S. K. LEWER.

32, Gascony Avenue,
West Hampstead,
London, N.W.6.

DX Records.

The Editor, E.W. & W.E.

SIR,—I have read with interest the letter published in your correspondence page of the issue of E.W. & W.E. for August, 1925, from Mr. J. A. Partridge.

I think he is labouring under a slight misapprehension regarding the details of my letter which was published, I believe, in your previous issue. As far as I can see, the details which Mr. Partridge publishes of the working of his own station 2KF, and also 5LF, have no bearing whatever upon the transmission which I made, and which, in spite of what he says, still remains the shortest wave-length used for such long distance transmission; also it was the first transmission on ultra-short waves in daylight to be made to Australia; of course, by this I do not mean two-way working. At the same time it might prove of interest to Mr. Partridge to know that my own station was working on the very short wave-lengths for quite a considerable period before his first two-way working with NFK.

No doubt you have another odd space in your correspondence page wherein to publish this letter, and if this is available I should be pleased if you would do so, for the information of those who are not in possession of the facts of some of these transmissions.

J. H. D. RIDLEY (G5NN).

"Studley,"
106, Woodside Green,
S. Norwood, S.E.25.

Station News.

The Editor, E.W. & W.E.

SIR,—Will you kindly publish in your next issue that the call letters of the Manchester Wireless Society are G6MX and that the permits covered by 2FZ, 5MT, and 5MS have been returned to the General Post Office, since when they have been re-issued. Perhaps the present holders of these three permits will notify listeners of their whereabouts through the medium of your columns. All communications for the Manchester Wireless Society and referring to tests of G6MX should be addressed to the Hon. Secretary, 66, Oxford Road, Manchester.

Station G5MB is worked by the Hon. Treasurer of the above Society from 808, Stockport Road, Longsight, Manchester.

GEO. P. EVANS, Hon. Secretary, Manchester Wireless Society.

66, Oxford Road,
Manchester.

The Editor, E.W. & W.E.

SIR,—Will you kindly note that I hope to be transmitting on 45 and 90 metres in the near future, in addition to the 150-200 metre band. Maximum power 10 watts, though I generally use much less. All cards will be acknowledged.

F. M. COOPER, B.Sc. (G6PF).

22, Guest Road,
Endcliffe,
Sheffield.

The Editor, E.W. & W.E.

SIR,—U2BW is now operating on 39 metres every day at 12 m. G.M.T. until 0300 G.M.T. I wish to Q.S.O. G's on 45-47 metres and 30-37 metres power input here 204 watts "S" rectified 60 cycles A.C.

U2BW will exchange a photo of station for reports on reception of signals that check with log.

I am a reader of your magazine and have not missed a copy in 3 years. Your paper is what we call a real good live wireless magazine. The technical end is very well presented and, I think, better than any we have here in the U.S.A.

Dr. A. L. WALSH (U2BW).

319, 33rd Street,
Woodcliffe on Hudson, N.J.

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The Editor, E.W. & W.E.

SIR,—This station is now working on 150-200 metres C.W. and phone. All Q.S.L. cards are answered and are very welcome.

With good wishes for your excellent paper,

F. ILLIDGE (5HG).

Main Street,
Frodsham,
nr. Warrington.

The Editor, E.W. & W.E.

SIR,—This Society will be greatly appreciative if you will give publicity to the fact that the Society's call sign is 2FZ and reports of reception should be sent to E. Butterworth, Esq., B.Sc., A.Inst.P., 102 Grenville Street, Stockport.

JAS. HUDSON (Publicity Secretary),
Radio Experimental Society of Manchester.
1, Dalton Street,
Hulme, Manchester.

The Editor, E.W. & W.E.

SIR,—It may be of interest to you that the P.M.G. has granted me a transmitting licence. My call letters are 6CT, power 10 watts, wave 150-200 metres.

I hope to be on the ether very shortly and will welcome all reports.

G. S. AITCHISON.

"Glenshee,"
58, Mildred Avenue,
Watford, Herts.

The Editor, E.W. & W.E.

SIR,—The call sign 2WK now replaces my old call sign 1XM and I will be glad to have reports of my transmissions.

Power, 10 watts: wave-lengths, 8, 90 and 150 metres.

W. A. HAYES.

"Moyallon,"
Portadown,
Ulster.

The Editor, E.W. & W.E.

SIR,—We beg to inform you that the call sign 5VR has been allotted to this company. Experimental transmission will shortly commence on wave-lengths of 23, 45 and 90 metres. Reports of the reception will be greatly appreciated and acknowledged and times of special tests will be sent to anyone on request.

We should esteem it a favour if you would insert a note to this effect in your journal.

H. RUBAND.

The Edison Swan Electric Co., Ltd.,
123-5, Queen Victoria Street,
London, E.C.4.

The Editor, E.W. & W.E.

SIR,—Please note that I have a licence for an artificial aerial transmitter at the address below, call sign 2BBQ.

E. H. CAPEL.

32, College Road,
Harrow.

The Editor, E.W. & W.E.

SIR,—The following may be of interest to some of your readers.

The call sign 6IZ has now been allotted to me. Input up to 10 watts; wave-length 90 metres. Reports on transmissions will be very welcome and all Q.S.L. cards answered by return.

EDWARD G. INGRAM.

18, Victoria Street,
Aberdeen.

The Editor, E.W. & W.E.

SIR,—I should be pleased if you would publish the fact that the call sign 6YC has been allotted to me.

The power employed is 10 watts, C.W., on wave-lengths of 150-200, 90, 45 and 23 metres. Reports will be welcomed, and Q.S.L's. acknowledged.

Wishing your excellent journal every success.

Fern Bank,

J. ROBERTS.

Endcliffe Rise Road,
Sheffield.

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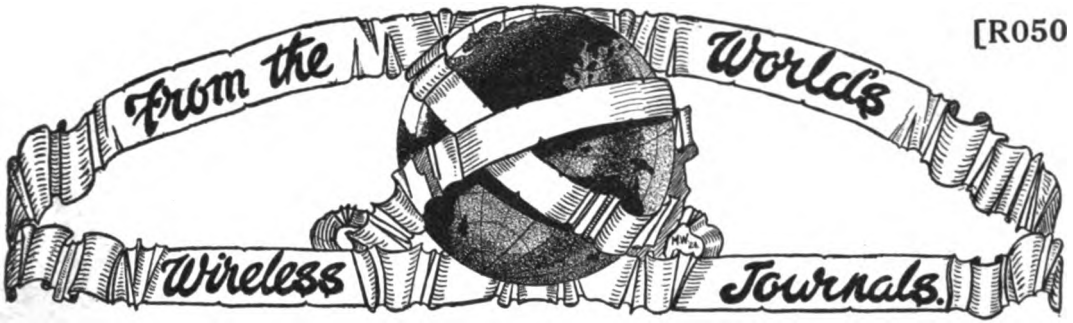

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R100.—GENERAL PRINCIPLES AND THEORY.

R113.4.—Radio Propagation.—G. W. de Tunzelman (*Electn.*, 17th July, 1925).

Eccles showed mathematically in 1912 that the presence of ions in the upper atmosphere would tend to bend horizontal waves downwards. Larmor has elaborated this theory recently. Practical observations suggest a greater complexity than that indicated by Larmor's theory. It is suggested that the ions exert a selective action on waves corresponding to various frequencies. If a simple periodic force be exerted upon an ion it will execute a free oscillation together with a forced oscillation. The component velocities become very large at a certain frequency which is a given function of the earth's magnetic field, the electric charge and mass of the ion and the velocity of wave propagation. By actual insertion of known values for these quantities a value for this critical frequency obtained corresponding to a wave-length of about 214. Practical experience shows that wave-lengths between 200 and 300 metres are about the worst for establishing long distance communication. Rays entering an ionised medium are resolved into two component rays which may travel at different velocities, have their planes of polarisation rotated to different extents and are bent to different extents.

R133.—Génération d'Oscillations Polyphasées au moyen de Tubes Electroniques.—Prof. R. Mesny (*Onde Elec.*, *June*, 1925).

By connecting *n* triodes in an arrangement having both geometrical and electrical symmetry it is possible to generate polyphase oscillations of *n* phases. The particular arrangement shown in Prof. Mesny's article comprises three identical triodes whose filaments are in parallel and whose anode circuits each have similar inductances connected in "star" formation. The grid circuits are also connected in "star" and are each coupled to their respective anode circuits. Three tuning condensers may be connected "in delta" between the extremities of the anode or grid "star" accordingly as anode or grid tuning may be required. That such a circuit is capable of generating three-phase oscillations is fairly obvious and in actual practice it has been found to do so with stability. A short analysis of the emission of a three-phase field is given and the important property has been found that with a frame aerial receiver the effect of a three-phase transmission can in general only be cut out at one orientation of the frame instead of at two as is usual. Various uses for high-frequency rotating fields suggest themselves. For instance it would enable a small rotating mirror to be rotated at very high speeds in a vacuum. A method is described of using a rotating H.F. field to measure phase relations in ordinary oscillatory systems such as amplifiers, etc.

R200.—MEASUREMENTS AND STANDARDS.

R248.—A Variable Resistance for Radio Frequencies.—R. M. Wilmotte, B.A. (*Exp. W.*, Aug., 1925).

An account of the construction of a continuously variable resistance of the order of one ohm, having constant inductance, capacity and geometrical form over its range.

R300.—APPARATUS AND EQUIPMENT.

R334.—Les Phénomènes de Résistance Négative dans les Lampes a Deux Grilles.—P. Amye (*Onde. Elec.*, July, 1925).

This article deals with the use of thermionic valves having two grids. One of the earliest of such valves was the pliodynatron of Hull, which had one grid very close to the filament and another very close to the plate, a positive potential being applied to the outer grid as well as to the plate. By this means it is possible to obtain a "negative resistance" characteristic which allows oscillations to be sustained in a tuned circuit connected in the outer grid circuit. The inner grid may be used to modulate the oscillations so produced. More recently double grid valves have been used in a somewhat different manner, the inner grid being given a positive bias to reduce the "space charge" effect while the outer grid and anode are used in the usual ways for regenerative detection, etc. Some dynatron characteristics of a certain French make of double grid valve are given. Some dynatron receiving circuits are described. Owing to the space-charge grid it appears that quite low anode voltages suffice. Most of the diagrams indicate an

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anode voltage of about 8. It is stated that distant stations can be received on such arrangements through atmospherics which would render their reception on ordinary valves impossible. No doubt this is due to some limiter action owing to the small anode voltage, but the author has not enlarged upon this point.

R342.—More about the Reflex.—P. K. Turner (*Exp. W.*, Aug., 1925).

Concluding portion of series of articles dealing exhaustively with the principles underlying the operation of wireless receiving sets.

R376.3.—Recent Advancement in Loud Speaker Reproduction.—Dr. J. P. Minton (*W. Age*, July, 1925).

Continuation of a series of articles on the problems of distortionless loud-speaker reproduction of broadcasting. Horn limitations in particular are dealt with. It is stated that the range of response of the average loud speaker horn is very limited, not covering more than about three octaves. The metallic sound of loud speakers in general is not due to the horn being made of metal, but to insufficient reproduction of the lower tones. A serious source of distortion is constituted by the resonant frequency peaks, inherent in practically all horns, which give undue prominence to impressed fundamental tones or harmonics of these frequencies. A striking instance is given of an experiment in which a pure sine wave current of 270 cycles was supplied to a loud speaker. A sound output oscillogram was obtained showing copious distortion, the amplitude of the second harmonic being over five times that of the fundamental and the amplitude of the fourth harmonic being nearly one and a half times that of the fundamental. As a result of experiments with horns the relatively long exponential type is preferred. Very satisfactory results have been obtained by combining two or three horns of different sizes in order to cover a large frequency range. The largest horn may have a total acoustical length of 7½ ft., while the smaller horns are of more familiar dimensions. It is said that by this means the range of reproduction has been increased to about six octaves or from 90 to 5 000 cycles.

Experiments were also made with a view to ascertaining to what extent a loud-speaker horn may be curved round for the sake of compactness without sacrificing quality. It was found that even a smooth curvature of large radius gives rise to a certain amount of reflection back towards the apex of the horn. Sharp right-angle bends are ruled out altogether.

R382.1.—The Self-Capacity of Inductance Coils.—H. J. Barton Chapple, B.Sc. (*Exp. W.*, Aug., 1925).

Description of the results of exhaustive tests made with both commercial and experimental coils.

R384.—Henrymètres, Capacimètres, Tellurohmmètres.—R. Barthélmy (*Onde Elec.*, June, 1925).

A description is given of some ingeniously designed instruments capable of giving direct scale readings in henries, microfarads or ohms accordingly as the instrument is designed to measure inductance, capacity or resistance. Taking the henrymeter first, this contains a small hand-driven magneto-alternator giving a few volts at 150 cycles. Across the output of this alternator is a fixed inductance of high value in series with the unknown inductance to be measured. The alternating potentials set up across the latter are rectified by a synchronous commutating rectifier on the shaft of the generator, the rectified potentials being applied to a sensitive moving-coil D.C. voltmeter. The voltmeter reading is directly proportional to the unknown inductance. If this inductance possesses ohmic resistance as well there will be an ohmic potential drop across it in addition to the reactive drop. It is shown, however, that the change of phase due to the presence of resistance upsets the synchronism at the commutating rectifier in such a manner as exactly to compensate for this resistance effect. Hence the scale deflection always indicates the inductance of the coil under measurement and is independent of its resistance. The readings are independent of the frequency but the voltage delivered by the hand-generator must be maintained at the right value. This implies turning the handle at the right speed, and in order to do this a button on the instrument is pressed and the generator handle turned at such a speed as to bring the pointer of the voltmeter to a specified mark on the scale; the button is then released on the rate of turning is maintained at the same value.

Capacity meters are constructed on very similar lines, condensers being employed in the place of the inductances in the circuit mentioned above. Here again the instrument reads the true capacity of the condenser under measurement no matter whether the dielectric is good or leaky.

Finally, a special form of ohmmeter is described. This again employs a hand-driven A.C. generator, which, however, is not directly connected to the measuring circuits but to the primary of a step-down transformer. Across the secondary of this transformer a fixed resistance and the unknown resistance are connected in series. Across the unknown resistance is shunted the rectifying commutator in series with a large fixed inductance. This commutator works off the generator shaft as in the other instruments and the rectified output operates a D.C voltmeter. The voltmeter reading is a function of the unknown resistance and may be calibrated accordingly. An advantage in this form of ohmmeter is that it may be used to measure the resistance of circuits already carrying D.C. currents or A.C. currents of a different frequency from that produced by the instrument generator. Such currents will not affect the meter reading.

R386.—Filters.—P. K. Turner (*Exp. W.*, August, 1925).

An account of the design of electric frequency filters. Filters may be designed to pass all currents above a certain frequency, to stop all currents above a certain frequency, to pass frequencies only within a specified limited band or to stop frequencies within a limited band. A method of calculating the requisite values of inductance and capacity for the various components of a filter to have specified electrical properties is developed. Stress is laid upon the importance of taking the actual working output load into account in designing any filter.

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(The following notes are based on information supplied by Mr. Eric Potter, Patent Agent, Lonsdale Chambers, 27, Chancery Lane, W.C.2.)

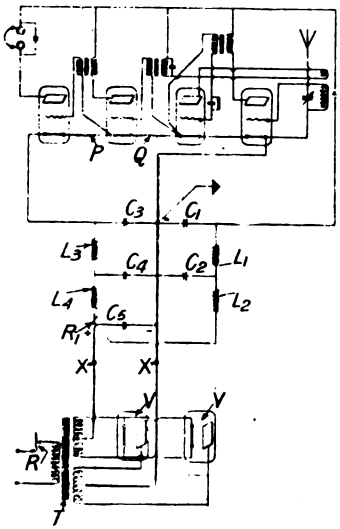
[R008

AN ALTERNATING CURRENT RECEIVER.

(*Convention date, France, 15th March,* 1924. *No.* 230,854.)

Yet another system for utilising alternating current for broadcast receivers is disclosed in the above British Patent, which is granted to the Société Française Radio-Electrique. The system is rather ingenious, and is one of the best which we have met, as it is adapted to be used with ordinary valves.

The alternating current supply is introduced to a transformer *T*, the primary of which is provided with a regulating rheostat *R*. The secondary consists of two centre tap windings. The low voltage winding is connected to the filaments of two rectifying valves *V*, while the high voltage winding is connected to the anodes of the rectifying valves.



The output is taken, of course, across points *XX*, *i.e.*, the centre tappings of the two windings. The output is led through a double filter consisting of two series of chokes and condensers, *L1 C1*, *L2 C2*, and *L3 C3*, *L4 C4*, *C5*. The first system is an ordinary smoothing device for the high tension supply, while the second system is for the filament supply, which is further controlled by a variable resistance *R1*. This second filter system contains enough resistance to lower the voltage to a suitable value for the filaments. The filaments, of course, are connected in series.

Additional grid bias is obtained for the last stages by the inclusion of extra resistances *P* and *Q* in the filament leads. Valves suitable for use with this circuit are, of course, of the 60 milliamp type on account of the small current delivered from the rectifier valves. Readers will probably find that experiments on these lines will prove very successful and probably afford one of the best solutions to the problem of broadcast from the experimenter's point of view.

RESISTANCE CONSTRUCTION.

(*Convention date, Switzerland, 14th March,* 1923. *No.* 212,912.)

A rather interesting method of constructing resistances which might be suitable for use in anode circuits is described in the above British Patent by E. Hediger. A quantity of powdered carborundum is mixed with a certain amount of retort graphite, the mixture being arranged to give a suitable resistance coefficient. This mixture, to which aluminium in powdered form may be added if desired, is pressed into shape with the addition of an oxide such as quartz or lime, and heated in an oven to a temperature of 1 800 degrees C., together with an air supply as an oxidising agent. This hardening produces a recrystallisation, so that a hard mass is produced which is not brittle. The resulting mass may then be heated to red heat, so as to temper it, which renders it somewhat softer, and more conductive, and also results in a uniform resistance throughout the mass. It appears that resistances built on these lines may be exceedingly useful for amateur purposes.

A DOUBTFUL INVENTION.

(*Application date, 30th April,* 1924. *No.* 234,965.)

A rather interesting, but probably doubtful invention is described by G. W. Hale and the Radio Engineering Company, Limited, in the above British Patent. The circuit shown in the accompanying illustration is said to be a modification of an ordinary dual amplification scheme. It will be noticed that an ordinary aerial circuit *L1 C1* is provided, and it is stated that first of all the valve V acts as a high frequency amplifier, a radio frequency potential set up across the inductance *L1* being conveyed to the grid by means of the self capacity between the windings of an iron cored low frequency transformer *T*. It is also stated that the amplified high frequency potentials in the anode circuit of the valve are introduced into the aerial circuit by virtue of the H.F. coupling between the coil *L2*, which is untuned, and the aerial inductance *L1*. It is further stated that these amplified potentials are rectified by a crystal detector *D*, which is in series with the primary of the low frequency

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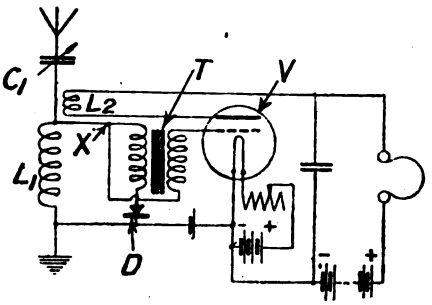
transformer. The secondary of this transformer is connected between the grid and the upper end of the aerial inductance, and it is stated that the valve functions as an ordinary low frequency amplifier. It is perfectly obvious that the scheme functions, and no doubt functions very well, but

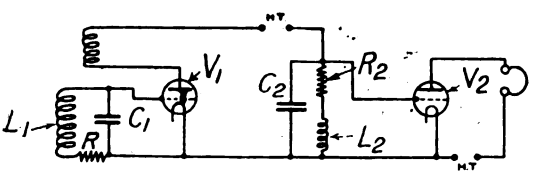


we ourselves do not consider that the above explanation is correct, the more probable explanation being as follows. The reader should notice particularly the connection of the lower end of the secondary winding of the transformer. This is shown connected at a point *X*, which happens to be the upper end of the aerial coil. It seems highly probable that the received oscillations are rectified in the first place by means of the crystal detector *D*, which is in series with the primary of the transformer, and these rectified oscillations are simply applied to the grid of the valve in the ordinary way, and the valve acts as an ordinary low frequency amplifier. So far as low frequency amplification is concerned, the connection at *X* might just as well be made to the earth in the usual manner. The fact that connection is made to the upper end of the aerial coil instead of the lower end does not affect the transformer to any extent as part of a low frequency amplifier scheme. In a modification of the system, the scheme indicated is shown preceded by an ordinary radio frequency amplifier.

NEUTRALISING DISTORTION.

(*Application date, 6th February,* 1924. *No.* 233,417.)

A very interesting scheme, which is represented more or less diagrammatically by the accompanying illustration, is described in British Patent No. 233,417 by P. W. Willans. It is pointed out that if reaction is used to an almost unlimited extent in broadcast receivers, the sharpening of the tuning gives unequal amplification over the entire range of side bands, and results in distortion. Obviously there is a greater reduction in the amplitude of



the higher side tones than in those of the lower side tones. Accordingly means are employed in the audio frequency stages which will increase the amplitude of the higher side tones, the amplitude of which has been decreased by radio frequency more than those of the lower side tones, which are comparatively unaffected by reaction. Referring to the accompanying illustration it will be seen that *V*1 is a regenerative valve in which the resistance of the input circuit *L*1 *C*1 is represented as *R*. In the anode circuit of the regenerative valve, and across the grid filament circuit of the valve *V*2, is connected a resistance *R*2, and an inductance *L*2, which are shunted by a by-pass condenser *C*2, the impedance of which to low frequency currents can be considered as very large compared with the impedance of *R*2 *L*2. The required correction is obtained by making the ratio of *R*2 to *L*2 half that of the effective resistance of the circuit *L*1 *C*1. It is stated that the value of the inductance *L*2 may be of the order of 0.2 henries, while the resistance *R*2 may be of the order of 3 000 ohms for use in conjunction with a regenerative valve having an internal resistance of about 100 000 ohms. The scheme is undoubtedly very ingenious, and should prove of considerable interest to amateur experimenters.

A MULTIPLE ELECTRODE VALVE.

(*Application date, 30th April,* 1924. *No.* 234,966.)

A form of multiple electrode construction for valves is described by E. Y. Robinson, E. J. E. Hubbard, and The Metropolitan-Vickers Electrical Company, Limited, in the above British Patent. Readers will notice the multiple electrode valve described in these columns, (see page 798) and devised by the Mullard Radio Valve Company, Limited, and S. R. Mullard, in which separate ribs of anodes and grids were placed round separate filament limbs. A very similar scheme is described in the present patent, application for which, it will be noticed, was made several months later. The accompanying illustration represents one method of constructing an anode. Two exactly similar sheets of metal *S*1 and *S*2 of rectangular formation are provided with two longitudinal, semi-circular channels, so that when the plates are placed together as shown, they form a double anode. The specification is very detailed, and describes several modifications, one modification being in the form of a cross, in which four channels are provided.

NON-METALLIC FILAMENTS.

(*Application date, 12th November,* 1923. *No.* 223,487.)

A system of non-metallic filament construction is described by W. R. Bullimore in the above British Patent. According to the invention oxides of alkalis and alkaline earth metals are mixed with an agglutinant material such as uncarbonised cellulose, which is squirted through dies, after which the resulting filament is sintered by raising it to a high temperature in an inert atmosphere. An alternative method is to heat it in a packing of graphite or magnesite, so as to exclude air and prevent injury to the filament during

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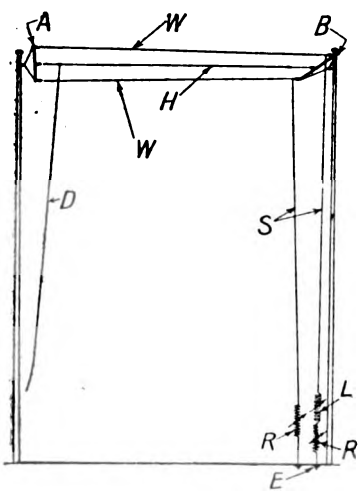
heating. It is stated that the advantage of this system is that the metal oxides cannot peel off the wire, and there is far less tendency for volatilisation or disintegration to occur.

INTERFERENCE FROM ELECTRIC SUPPLY.

(*Application date, 6th February, 1924. No. 233,416.*)

Broadcast listeners and amateur experimenters are frequently inconvenienced by interference arising from the proximity of public supply systems, or motors or lifts in action in the neighbouring buildings. A method of eliminating this trouble is claimed in British Patent No. 233,416 by T. G. Threlkeld and W. W. Butterfield. The invention is illustrated by the accompanying diagram, from which it will be seen that the scheme is associated with the actual aerial system. An ordinary aerial consisting of a horizontal portion *H* and a down lead *D* is provided in the usual manner. In close proximity to the horizontal portion of the aerial are a number of wires *W*, which are insulated at the ends *A* and *B*. The down-leads *S* from these wires are connected to earth at *E* through resistances and inductances *R* and *L*, which act as damping devices. It is stated that the normal receiving aerial has to be connected to a gauze or other earth mat, or alternatively, to counterpoises. No definite explanation is given, but it would appear that the wires *W* and down-leads *S* simply form an ordinary screen which is affected by an inductance. The object of the damping system appears to be merely to render the screening aperiodic so as not to affect the normal tuning system to any appreciable extent.



A TWISTED FILAMENT.

(*Application date, 15th January, 1924. No. 232,320.*)

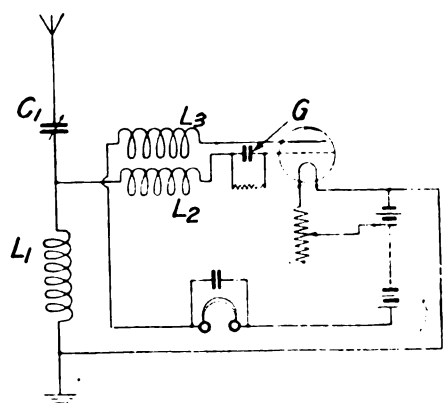
C. Seymour and H. R. Cantelo describe in the above British Patent a method of constructing a filament which consists essentially of plaited or woven wires. In the case of thick filaments, designed to give a very large emission, as is needed in high power transmission, considerable difficulty is frequently experienced in adequately supporting and keeping in tension a normally thick wire. A thick filament is somewhat liable to fracture, and is unsuitable on this account. Accordingly the filament is constructed on the lines of a cable or rope made of thin tungsten or similar material woven or braided together to form a cable. It is said that a cable of this description has greater tensile strength and has a much larger surface area than a single wire filament of the same overall diameter. We should imagine that the system would be very successful.

A REVERSE REACTION CIRCUIT.

(*Application date, 12th February, 1924. No. 232,363.*)

A rather peculiar reverse reaction circuit is described in the above British Patent by H. J. Warner and H. Tyler in British Patent No. 232,363.

Referring to the accompanying illustration it will be seen that an ordinary tuned aerial circuit $L1$ $C1$ is provided, and between the grid connection (which includes a grid condenser *G* and leak, since that valve is functioning as a rectifier), and the output of the aerial inductance another inductance $L2$ is included, while a third inductance $L3$ in the anode circuit is coupled to the inductance $L2$. It is stated that electrostatic reaction is obtained almost to the point of oscillation essentially by virtue of the capacity which exists between the electrodes of the valve. By making the grid condenser *G* of very small value the electrostatic reaction will not vary to any considerable extent if the coils $L3$ and $L2$ are moved. The coil $L3$ is arranged so that reverse electromagnetic reaction is obtained. It is stated that by adopting this circuit very much louder and purer signals are obtained, but we do not see why this should be the case. The amount of regenerative amplification obtained with any given valve is determined by the amount of positive reaction which exists in the circuit, and since we have here a balance between positive electrostatic reaction and negative electromagnetic reaction, we fail to see why the arrangement should give better results. It appears that it might be due to the fact that the circuit is better balanced, and that there is no tendency for sustained oscillations to occur until the maximum amount of positive reaction has been introduced; in other words, the tendency for overlap exists. The circuit, however, should prove of considerable interest to experimenters.



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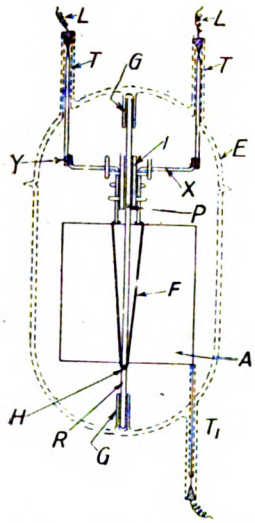
SUPPORTING THE FILAMENT.

(*Application date, 1st January, 1924. No. 231,580.*)

A method of supporting the filament is described by C. Seymour and H. G. Hughes. Essentially the invention consists in keeping the filament taut by supporting it on a metal rod extending throughout the end of the valve. The accompanying illustration shows the invention as applied to a two-electrode rectifier valve suitable for high-power work. The envelope *E* may be of silica and is provided at each end with two guide tubes *G*, which hold the supporting rod in position. The rod is provided with a metal hole or slot *H*, to which a hairpin filament *F* is attached. The rod also carries a special form of insulator *I*, which is pinned to the rod at *P*. The ends of the filament are attached to end-pieces *X*, which are bound at *Y* to the filament leads *L*, which are sealed into tubes *T*. The anode is shown at *A*, and the lead is taken through another tube *T*1, which is sealed in in the normal manner.



PROTECTING COATED FILAMENTS.

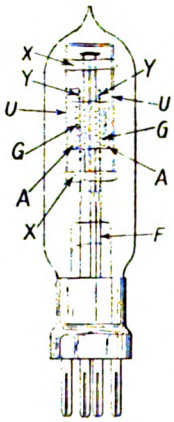
(*Application date, 7th March, 1924. No. 234,565.*)

A very interesting method of protecting coated filaments is described by E. Y. Robinson and Metropolitan-Vickers Electrical Company, Limited, in the above British Patent. It is stated that although a coated filament is comparatively robust and can be handled without special care, it is liable to deteriorate owing to exposure to the atmosphere. The well-known oxide coating combines readily with water or carbon dioxide to form hydroxides and carbonates which are liable to become detached from the filament and ruin the coating. Accordingly coated filaments have previously been kept away from the atmosphere, and the process of assembling and initial exhaustion has to be carried out very quickly. This difficulty is obviated by covering the coated filament with an impervious protecting medium such as an organic gum. One method is to dip the coated filament into a solution of nitro-cellulose in amyl acetate. When the protected filament is sealed into the valve the coating can be flashed off in the usual way. We should imagine that the scheme would be quite successful in practice.

A MULLARD MULTIPLE ELECTRODE VALVE.

(*Application date, 15th January, 1924. No. 232,318.*)

A rather interesting form of multiple electrode valve is described by the Mullard Radio Valve Company, Limited, and S. R. Mullard, M.B.E., M.I.R.E., in the above British Patent. The invention relates particularly to valves employing looped or hairpin type filaments, and consists essentially in providing each filament with its own group of associated electrodes. The simplest embodiment of the invention is illustrated by accompanying diagram, in which the valve shown employs a hairpin type of filament. It will be seen that the electrodes are mounted on a frame which consists of two insulating cross bars *X*, and two uprights *U*, which also support the filament at *Y*. The cross members *X* carry the two grids *G* and the two anodes *A*. The leads from the electrodes are taken out in the usual way through a foot *F*, and the valve is provided with the usual base and plugs. A similar construction is used for a valve containing three or four sets of electrodes. It is stated that the advantage of a construction of this type is that the electrode path between each limb of the cathode and its respective anode is shortened as much as possible, and has a much larger cross section than valves having a looped filament and a single anode enclosing the whole of it. It is stated that for this reason the amplification factor and the electrical characteristics of the valve are very considerably improved. The valve is certainly extremely novel, and it would be very interesting to test one not only on signals, but to measure its various inter-electrode capacities.



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EXPERIMENTAL WIRELESS & The WIRELESS ENGINEER

VOL. II. OCTOBER, 1925. No. 25.

Editorial Views.

Selectivity.

IN view of the increasing tendency (due to the very small current consumption of modern valves) to use multi-valve sets for reception except on ultra-short waves, there is considerable interest attached to the article on selectivity in this issue. At first sight, one might wonder why the question is connected with multi-valve sets; why, in fact, it has not been the practice to use several tuned circuits coupled together to get selectivity apart from the amplifier. The reason, however, is simple. A set of several coupled circuits has several natural frequencies, even if all the circuits are tuned alike. It is, in fact, a filter, and must be designed as such.

But the same circuits connected to one another by valves behave in a radically different manner, because they do not react on one another—except, of course, to a small extent *via* the valve capacity, in sets not neutralised.

The great selectivity which may be obtained in multi-stage sets makes it necessary to adopt a special point of view; one must be on one's guard against *excessive* selectivity. Consideration of this point, in connection with the methods developed in the article, throw into prominence a curious point in the case of multi-stage receivers designed to tune over a considerable range; that if it is desired to maintain constant selectivity, the condensers should be practically fixed, and the inductances should be varied. Otherwise the set must be more selective on long than short waves.

As far as the writer remembers, this is a point not previously brought out.

Directional Reception.

We publish also in this issue an article on the methods adopted at certain commercial stations to diminish interference from atmospherics and unwanted stations by getting sharp directional effects. It is unfortunate that the most effective of these methods are hardly practicable for amateur working. But simplified versions of them may be very useful. For example, during the recent pan-European broadcast tests, we were working on a high power set and frame, in order to cut down interference and also to get help from the directional effect in identifying stations. In several cases it was found that the use of either a rather long earth wire or a small indoor aerial connected to the set as well as the frame gave a quite useful approximation to a "heart-shape" diagram, and was of great assistance. By connecting both to the set by untuned transformers with variable coupling even better results are obtainable, though with reduced signal strength.

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Supersonics.

We were impressed, on our various visits to the Albert Hall Show, with the comparative absence of "freak" sets. On the other hand, the supersonic has undoubtedly come into its own. Naturally, the sets exhibited are exclusively for broadcast work. But it appears to us that the possibilities of this set for long-distance short-wave work are not yet fully recognised. After all, straight H.F. amplification is not so very difficult at 300 metres, and yet the supersonic is getting more and more popular for that work. On 50 or 20 metres, where (at present) straight H.F. amplification seems impracticable, it should have even greater claims for notice.

Many readers, we believe, are rather frightened of the supersonic, perhaps owing to the weird terms ("filters," for example) used by our Transatlantic cousins in describing it. But if one just sits down and starts to design out, on one's own, a combination of a 1-valve receiver, a separate oscillator for short waves, a long-wave amplifier, and a long-wave oscillator for the beat note, one can go ahead very comfortably.

Although it is not our usual practice in E.W. & W.E. to give detail designs of sets, we are thinking of doing so in this instance, and giving particulars of a fairly successful set with which we have been working lately. At the same time we should be very glad to use similar descriptions of sets built by readers. It should be noted that we want above all the *principles and methods used in the design* rather than a bald description of the final set.

Why we give Space to Esperanto.

From time to time a few British readers of E.W. & W.E. complain because we devote some space to material in Esperanto. They suggest that those who wish to learn this language are provided for elsewhere; and this is undoubtedly true.

But we should like readers to realise that (although we began with an Esperanto dictionary of wireless technical terms and a sketch of Esperanto grammar) the articles and abstracts now appearing are not primarily intended as Esperanto lessons for British readers, but are provided for their wireless interest to our many foreign readers.

It is, in fact, possible that in the future there will be an international arrangement by which leading wireless technical journals will publish Esperanto abstracts of their own contents, so that readers in other countries may derive benefit from them.

Lest it may be thought that this is just some personal fad, it may be mentioned that the use of Esperanto for such purposes has just been exhaustively investigated by a strong conference in Paris. We give just a few of the persons and institutions represented—those whose names are familiar to us: d'Arsonval, Berthelot, de Broglie, Gen. Ferrié, Lebesgue, Lumière, Painlevé, Perrin; British Association for Advancement of Science ("B.A."); French Association for Advancement of Science; American Association for Advancement of Science; American Mathematical Society; French Mathematical Society; Physical Society of London; Zoological Society of London; British Medical Association; French Society of Electricians; Carnegie Institute; Franklin Institute; Messrs. Gaumont; Messrs. Michelin.

In all, there were 130 societies and institutions and 120 well-known scientific individuals, belonging to 19 countries.

All agreed in recommending the use of Esperanto for expressing the results of scientific work, so as to make the information available to all countries; and we ourselves recommend readers, who are interested in learning what work is being done in other countries, to follow the lead of the Conference.

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Selective Amplifiers.

A short review of the question of Correct Selectivity, with simple graphs and charts for design purposes.

By P. K. Turner. **[R342·6**

A POINT on which the user of receiving apparatus has as a rule rather vague ideas, is the best means of getting the correct selectivity in H.F. amplifier circuits. We say the "correct" selectivity, for it must be realised clearly that excessive selectivity is quite possible. In telephony there is the well-known effect of loss in high notes due to "cutting" the side-bands. In telegraphy—especially high-speed work—there is trouble due to "rounding off," the dots and dashes no longer having sharp outlines.

It may be of interest, then, to show a quite easy way to design the coupling circuits to get just what is wanted. A fundamental point (mentioned not long ago in E.W. & W.E.) is the difference in the type of resonance curve obtained by (A) using one highly-selective stage and several quite untuned, or (B) by the same overall selectivity given by several equal fairly "flat" circuits. This point will be considered in due course.

The fundamental circuit to be considered is that of Fig. 1*a*, that known as "tuned anode." It should be noted that any "bridge" or "neutrodyne" methods of

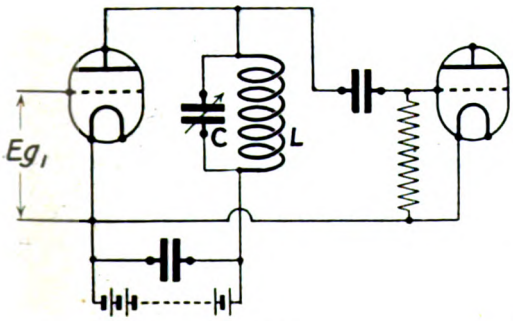

Fig. 1*a*.

stabilising will in no way affect our calculation, provided that the two items L and C are understood to be the coil and condenser actually forming the anode "rejector." The case of the transformer-coupled amplifier is essentially similar, provided that any capacity or resistance across the secondary is "transferred to the primary." This means that if S is the turns ratio, a condenser C' across the secondary is treated as one of capacity S^2C across the primary, and a resistance R_e across the secondary treated as one of R_e/S^2 across the primary.

Now the effect of an alternating voltage E_{g1} on the grid of the first valve is to apply a perfectly definite alternating voltage μE_{g1} (where μ is the voltage amplification factor of the valve) to the anode circuit, in addition

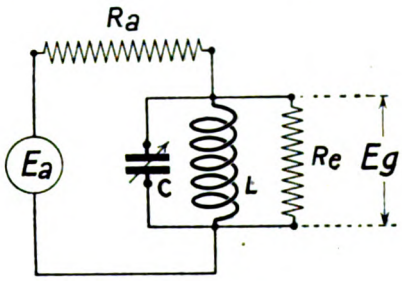

Fig. 1*b*.

to the D.C. voltage from the battery. Some of this voltage is used to drive the alternating anode current through the valve's own resistance; the rest to drive this current through LC. It is only this latter voltage that is transferred to the next grid.

Therefore, the measure of efficiency of the coupling is the fraction E_{g2}/E_{a1}—or, as we shall call it for simplicity, E_g/E_a—, where E_a is the same as μE_g, and is the alternating voltage put out by the first valve.

For purposes of calculation (which is carried out in the Appendix) we re-draw Fig. 1*a* in the form of Fig. 1*b*, where E_a is a generated voltage, R_a the anode impedance of the valve itself, and R_e the resistance of the grid circuit of the next valve. The resistance of the H.T. battery is neglected: it is supposed to be shunted by a condenser of reactance negligible at the working frequency.

In order to give the result of analysing the circuit in the simplest and most general form, we shall denote some of the important

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relationships in the circuit by letters. First, let ψ be the phase difference of the coil, which is its resistance divided by its reactance at the working frequency. We elected to base our calculation on ψ rather than on the actual resistance of the coil because, although both vary with frequency, the phase difference is usually the more nearly constant of the two. Next, let m be the ratio of the anode resistance of the valve to the reactance of the coil at the working frequency: it will be seen later that this is the controlling factor for selectivity. Next, let p be the "tuning ratio" of any frequency, *i.e.*, if λ_0 is the wave-length to which the circuit is tuned, and λ any other wave-length, then $p = \frac{\lambda_0}{\lambda}$. Lastly, let η be the "efficiency," *i.e.*, the ratio E_g/E_a already mentioned. Then (as shown in Appendix I.) to a close approximation

$$\frac{1}{\eta^2} = \underbrace{\left(\frac{R_a}{R_e} + 1 + m\psi\right)^2}_{(A)} + \underbrace{m^2\left(p - \frac{1}{p}\right)^2}_{(B)} \qquad (1)$$

Before going on to give detailed results from this equation, it is interesting to note some general features. First, it must be remembered that to get selectivity we do not want η to be always large or always small. We want it to be large for tuned signals ($p=1$) and small for untuned ones. Now the expression for $1/\eta^2$ comprises two parts, A and B, of which the first is not affected by tuning, while the second is. To get selectivity we want A to be small, so that B shall have as large an effect as possible on the value of η. For this purpose the first thing is to make R_e large, which means a well-designed grid circuit. (Note that we have not allowed for the capacity of this, because it is included with C.) In practice, R_a/R_e will almost always be considerably smaller than 1. Next, we should keep ψ small. But if m is going to be small this will not be so important, for then the product $m\psi$ will almost certainly be only quite a small factor compared with 1.

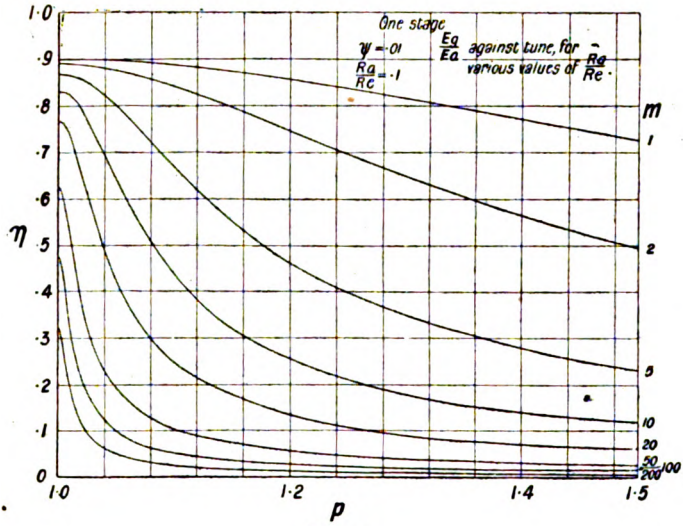

Fig. 2.

It is important to note that changes in A have the greatest effect on currents to which the circuit is tuned, while changes in B effect others more. It is therefore bad practice to control excessive selectivity by increasing ψ (as by using bad coils, or "lossing"), because this increases A without affecting B. An increase of m increases A also, but in addition effects a greater increase in B, and therefore decreases the selectivity without such a large loss of efficiency.

It will be the general rule, then, to get the correct selectivity by adjusting the value of m: small m, *i.e.*, large coil (and small condenser), for flatness; large m, *i.e.*, small

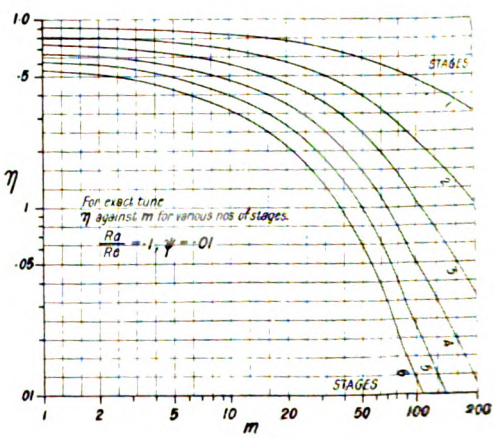

Fig. 3.

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coil (and large condenser) for sharpness. High magnification valves usually have high anode impedance, and hence call for larger coils and smaller condensers.

Any attempt to show actual effects in typical circuits is rather handicapped by the large number of variable factors: R_a, R_e, L, λ, and ψ, might all vary. We decided therefore to investigate only one value of R_a/R_e and one value of ψ. The value chosen for R_a/R_e was .1. It is by no means easy to assess the real value of this, for R_e varies according to the type of the second valve and the load in *its* anode circuit, and depends also on frequency. It is probable that at short wave-lengths R_a/R_e is really quite considerably larger than .1. But, as stated above, a change in its value causes a much smaller change in η, and, further, does not greatly affect selectivity. The same considerations, luckily, hold as regards ψ, so we selected for ψ a fixed value of .01. This is a reasonable value for good plug-in coils of medium inductance value—"50 to 200 turn" coils: smaller ones are likely to be better and larger ones worse. But, as we have stated, any divergence in ordinary practice from our chosen values of R_a/R_e and ψ will not greatly affect the results as regards selectivity.

From now onwards, then, we adopt as fixed

$$\frac{R_a}{R_e} = .1, \ \psi = .01.$$

Our first step was to calculate out and draw the resonance curves for one stage of such an amplifier for various values of m. These will be seen in Fig. 2, where η is plotted against p for values of m from 1 to 200. Both the outstanding features are very clearly shown here. There is a drop in efficiency, from .9 for the largest coil ($m=1$) to .32 for the smallest ($m=200$); and at the same time there is a very large change in selectivity. In Fig. 3 we show how, for exactly tuned signals, the strength falls off as the selectivity is increased by using large values of m. The reduction is shown for varying numbers of stages.

But it is not quite easy to see in Fig. 2 just how one curve compares with another; a much truer comparison is got by first multiplying each curve by a factor which brings the efficiency at exact tune ($p=1$) up to one fixed value; and secondly by using a logarithmic scale for η. These two changes have been made in Fig. 4. In this diagram the steepness of any curve at any point is a true measure of the selectivity; also, this type of curve is especially useful in dealing with multi-stage amplifiers.

Fig. 4 lays bare a very unfortunate difficulty in set design. Suppose, for example, we have found that in order to get the side-bands we must include signals "5 per cent. off tune," *i.e.*, $p=1.05$, and that we wish to get them at not less than .8 of the strength of the carrier wave. Then we see from Fig. 4 that the highest permissible value of m is 10. This means that signals 20 per cent. off tune ($p=1.2$) will come in at a strength of about .31. If we wish for better selectivity we must sacrifice part of the side-band.

The difficulty is avoided by using several stages each one of the same moderate selectivity, instead of one highly-selective stage and several untuned ones. That this is so is seen from Fig. 5. It is fairly obvious that if one stage cuts a certain signal down to .8 of its original value, two stages will cut this down again, making it $.8 \times .8 = .64$. With the logarithmic scale, this means simply that every point on the "2-stage" curve

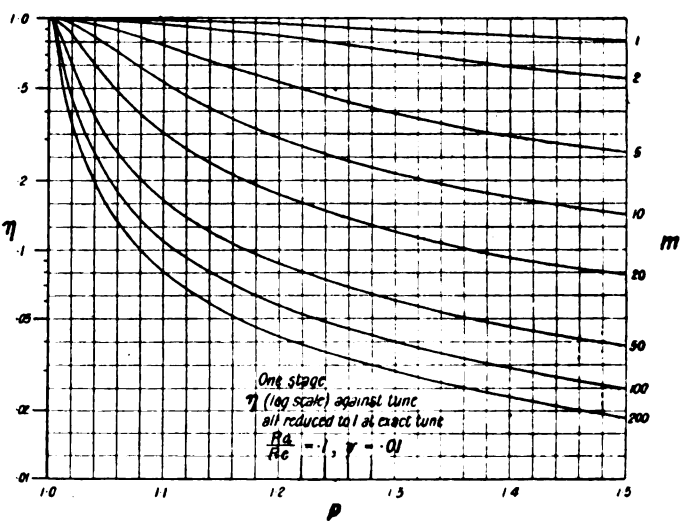

Fig. 4.

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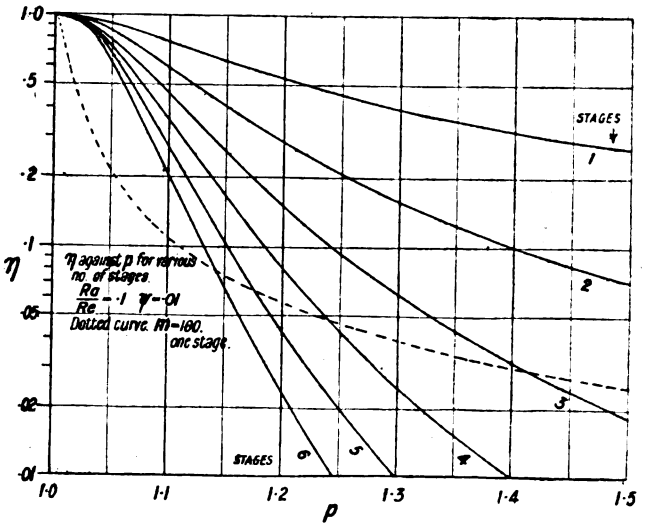

Fig. 5.

will be twice as far from the top of the sheet as the corresponding point on the "1-stage" curve, and thus we get Fig. 5.

Note, that in saying that a stage of amplification "cuts down" a signal, we really mean that the *coupling* does so. The accompanying valve will then magnify the remainder. Thus: strength of original signal 1. After first valve (of $\mu=5$, say), the strength is $1\times5=5$. After first coupling (giving a reduction to .8, say), strength is $5\times.8=4$. After second valve, strength is $4\times5=20$; after second coupling, $20\times.8=16$.

Let us tabulate these values for efficiencies of 1, .8, and .6 respectively:—

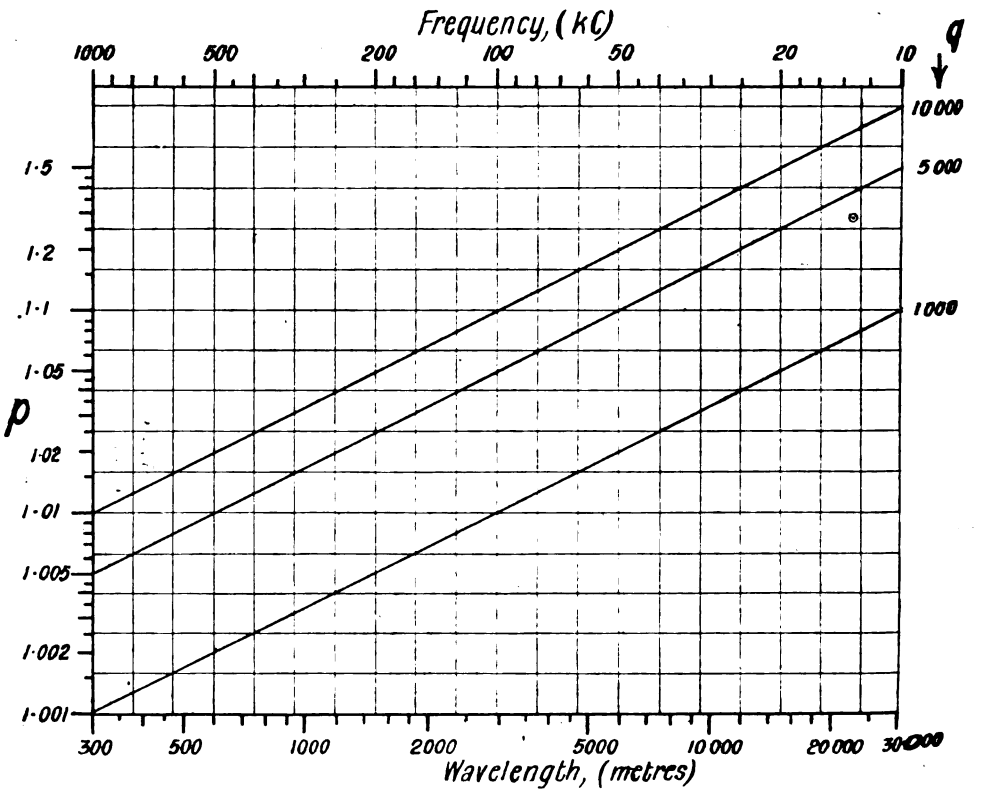

Fig. 6.

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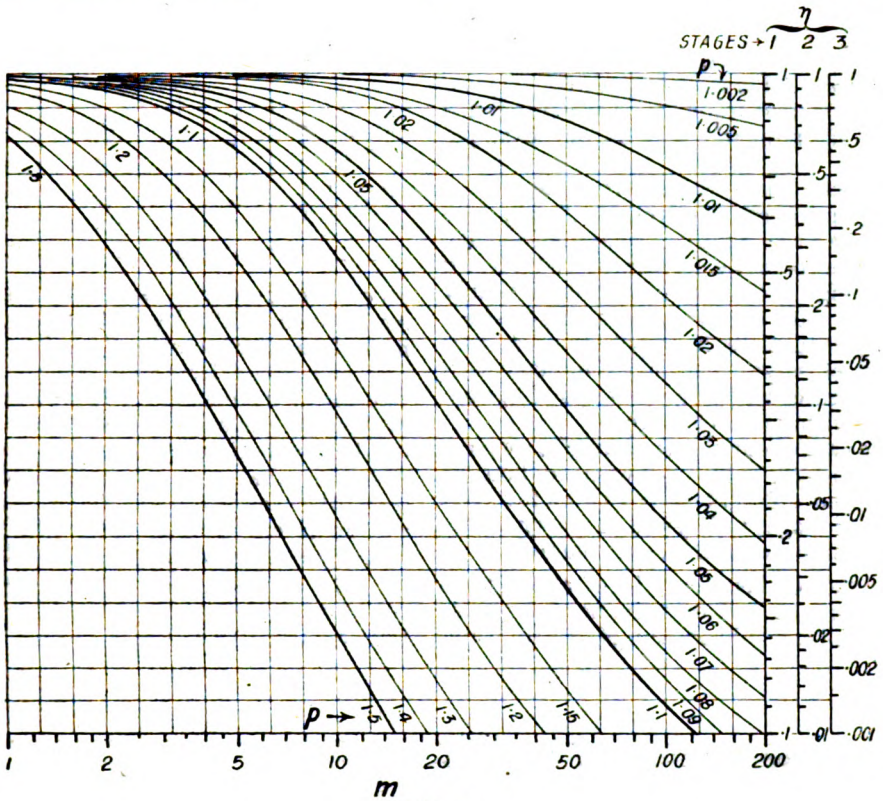

Fig. 7.

Efficiency	Signal	After 1st valve	After 1st coupling	After 2nd valve	After 2nd coupling
1	1	5	5	25	25
·8	1	5	4	20	16
·6	1	5	3	15	9

Comparing the initial and final results, we see how the reduction in the coupling increases selectivity.

The multi-stage curves in Fig. 5 are all for a circuit of rather low selectivity ($m=5$), except the dotted one, which is that of a single selective circuit ($m=100$) introduced from Fig. 4 for contrast. It is hardly necessary for us to point out the increased admission of nearly tuned "side-bands" of the multi-stage curve, combined with its better elimination of signals considerably off tune.

It will be appreciated, of course, that this is not necessarily an advantage. For telephony, it is of course a necessity. But for amplifying a single unmodulated frequency before allowing a local heterodyne to beat with it, the curves of Fig. 4 are more suitable, and it will be best to get the required selectivity by a few extremely selective circuits rather than by many moderate ones—additional stages, if required for strength, being aperiodic.

Now as to the design of an amplifier. We assume that the question to be solved is something like the following: "I want to amplify at 3 000 metres, to include side-bands given by audio frequencies up to 5 000 cycles; permissible drop not below .8; anode impedance of valves, 30 000 ohms."

The first question, then, is as to the amount of de-tuning (*i.e.*, value of p) required by a given modulation frequency on a carrier of given wave-length. This is solved by Fig. 6. Here wave-length is read along the bottom or radio frequency along the top, and lines are given for 1 000 cycle modulation for

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telegraphy, and 5 000 and 10 000 for telephony, the latter being preferable if it can be managed. This modulation frequency we are calling q, and from Fig. 6 we can find p for any given q and λ: in our example $p=1.05$.

The next task is to find the value of m which, for signals of given "p," will give not less than the requisite strength of signals. For this purpose we have prepared Figs. 7 and 8. Fig. 8, it may be noted, is simply the upper part of Fig. 7 to a larger scale. In order to deal with amplifiers of various numbers of stages, we have provided each of these figures with several scales of η, each for a given number of stages.

In the case of our chosen example, we have $p=1.05$, $\eta=.8$; and we wish to find m. We can find different values of m for each number of stages; they are as shown in the table at the head of the next column.

The choice between these alternatives depends on the desired reduction of signals further off tune. There are, of course, many

Stages	m	η for $p=1.2$	η for $p=1.5$
From Fig. 7 1	9	·34	·16
2	6	·22	·05
3	4·5	·18	·025
From Fig. 8 4	4	·14	·012
5	3·5	·13	·007
6	3	·12	·004 5

other considerations, such as the cost of many stages, difficulty of handling, required final strength of signals, etc.; but these are problems apart from the one we are considering at the moment. It may be that the number of stages is already fixed by other considerations, in which case m is now settled. Assuming that we are not limited by any such other considerations, let us take it that we are faced with jamming which is at a difference of wave-length given by $p=1.2$ or 1.5. Then the third and fourth columns of the table above show what is the comparative strength of this jamming.

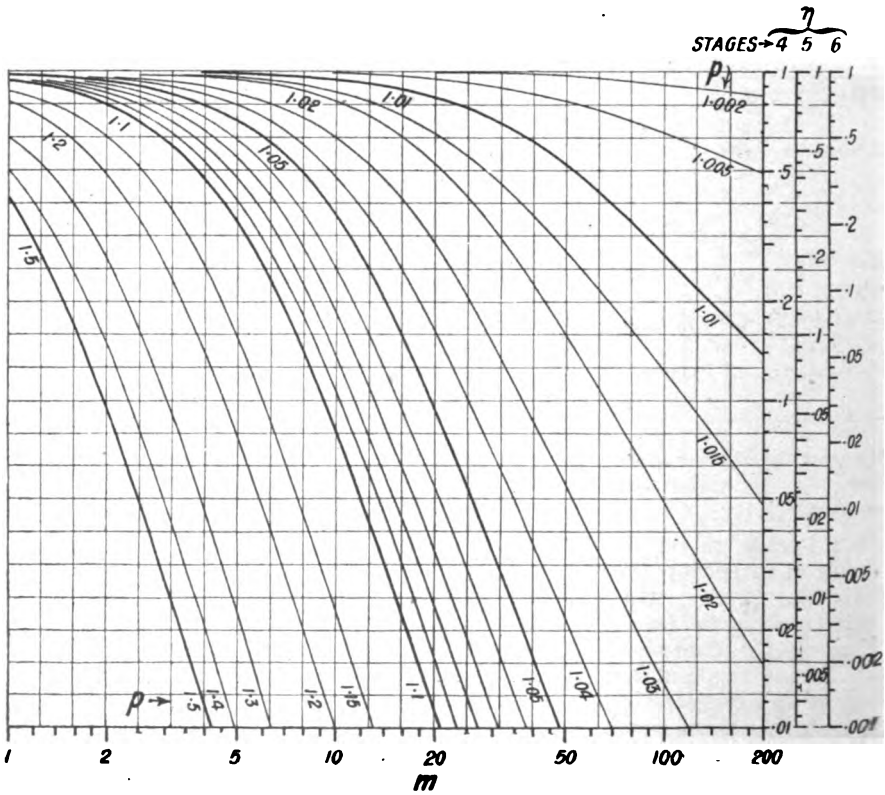

Fig. 8.

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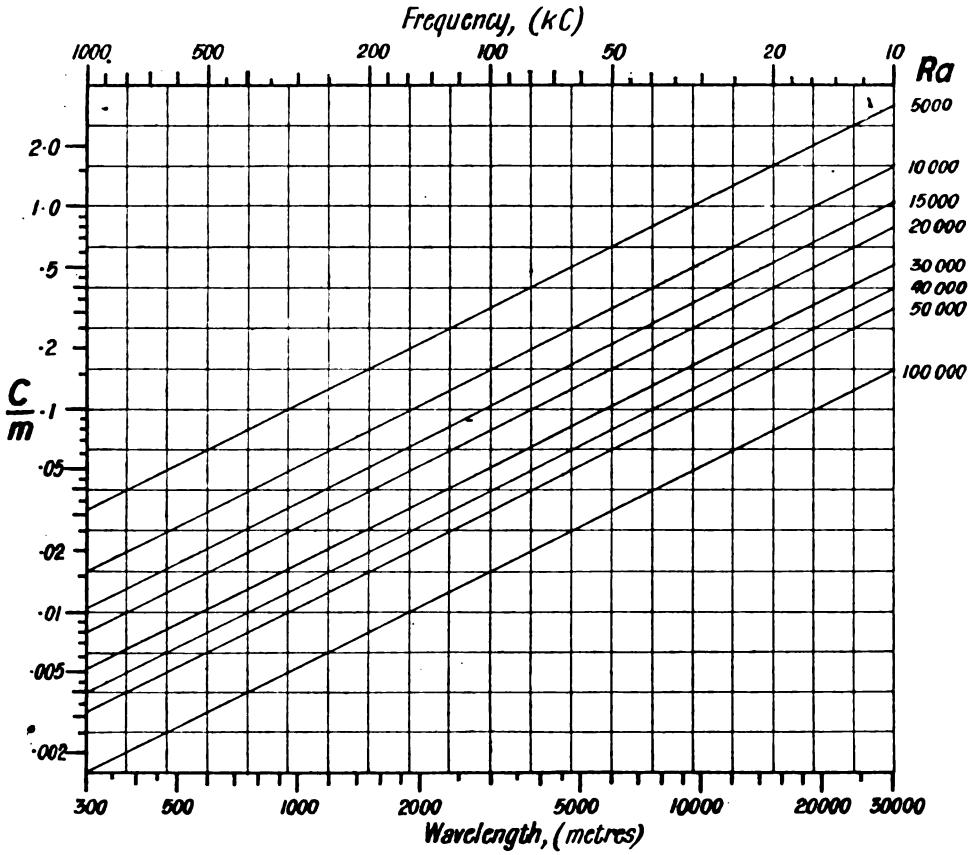

Fig. 9.

It would appear that three stages, $m=4.5$, would be the best compromise between economy and efficiency in the first case.

Having found m, we are in a position to evaluate the required inductance of our coil. But here a most interesting point crops up.

It is well known, and is confirmed by Fig. 6, that for a given q (modulation frequency), p increases as the wave-length goes up. Figs. 7 and 8 show that, for a given minimum of η, m must decrease as p goes up, and therefore as λ goes up. But $m = R_a/X_o$, where X_o is the reactance of the coil at the tuned frequency. Now, at the tuned frequency, the reactance of coil and condenser are equal—that is the definition of resonance. The reactance of a condenser is $1/2\pi fC$, so we have $m=2\pi fR_aC$. Now, we have just shown that m must increase as f goes up (this is the same as a decrease as λ goes up). If m and f increase exactly together, we see that, if R_a does not change, C will not either: in fact, the same condenser value will be right for all frequencies: only the coil should be changed. In actual practice m does not vary exactly in proportion, so that the required capacity is not exactly the same for all frequencies. But a change of wave-length from 300 to 30 000 metres may only cause a change of 30 or 50 per cent. in the capacity. For this reason we shall give details as to how to find C, and not L, from the data we have already got together. L can always be found from C and λ.

It will be remembered that we have already shown how to find m. Fig. 9 gives a means of finding C/m, and on multiplying this by m we have C at once. Fig. 9 has lines for values of R_a from 5 000 ohms, for power valves of fairly low μ, up to 100 000 for valves such as the "Q." As a rule, it will be from 20 000 to 40 000.

Fig. 10 shows capacity required against frequency, for three random cases, worked

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out in this way. It will be noted that practical working conditions, most happily, nearly always lead to a capacity of convenient value. As was stated above, the

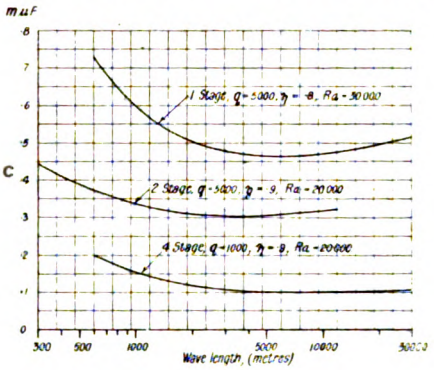


Fig. 10.

frequency effects nearly cancel out, the largest condenser for any one case being only twice that of the smallest throughout the whole range of frequency.

Lastly, before we repeat and summarise the working instructions, we feel inclined to say a few words on the cases where this question of correct selectivity may be really important. The outstanding example, of course, is in the supersonic set for telephony, where its effects are very obvious, and in fact act as a definite limit on the selectivity. But this is by no means the only case. A carefully stabilised H.F. amplifier of high power may show the effect quite distinctly on short waves.

An interesting point crops up in connection with heterodyne reception. If an H.F. or supersonic amplifier is being used, it is obviously best to defer the introduction of the beat supply to the latest possible point; for before its introduction we are dealing with a single pure frequency without side-bands, and can get extreme selectivity. Afterwards, this is not the case.

SUMMARY.

Given λ, the wave-length to be received; q, the modulation frequency; η, the minimum permissible strength of the edge of the side-band, compared with that at the carrier; and R_a the anode impedance of the valve:—

Turn to Fig. 6, and from λ and q find p: then turn to Figs. 7 or 8, and from p and η find m: decide on the number of stages, which will affect m. Last, turn to Fig. 10, and from λ and R_a find C/m. C is got by multiplying these two results, and will be given in $m\mu$F ($1m\mu F = .001\mu F$). L can be got from the well-known formula

$$\lambda = 59.7\sqrt{CL}$$

or

$$L = \frac{\lambda^2}{3\,550C},$$

which gives it in microhenries.

APPENDIX I.

Referring to Fig. 1*b* of the article, reproduced here for reference; if the coil L has a resistance R, and the losses in condenser C are neglected, let Z be the operator impedance of the circuit comprising C, L, R, and R_e.

Then

$$\frac{1}{\dot{Z}} = j\omega C + \frac{1}{R + j\omega L} + \frac{1}{R_e} \quad .. \quad (1)$$

$$= \frac{j\omega C R R_e - \omega^2 L C R_e + R_e + R + j\omega L}{R_e(R + j\omega L)} \quad .. \quad (2)$$

$$\text{or } \dot{Z} = R_e \frac{R + j\omega L}{R_e(1 - \omega^2 LC) + R + j(\omega L + \omega C R R_e)} \quad .. \quad (3)$$

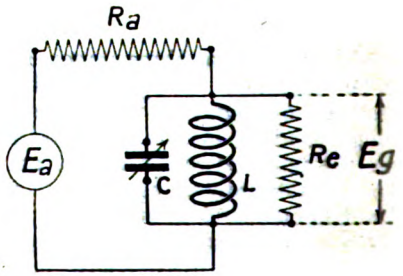
Now the total impedance of the circuit is

$$\dot{Z}' = \dot{Z} + R_a \quad .. \quad .. \quad (4)$$

$$= \frac{R R_e + j\omega L R_e + R_a R_e(1 - \omega^2 LC) + R R_a + j R_a(\omega L + \omega C R R_e)}{R_e(1 - \omega^2 LC) + R + j(\omega L + \omega C R R_e)} \quad .. \quad (5)$$

from this, if Z' is the magnitude of $\dot{Z}'$,

$$Z'^2 = \frac{A^2}{B^2}.$$



where

$$A^2 = [R R_a + R_a R_e + R_e R - \omega^2 L C R_a R_e]^2 + [\omega L(R_a + R_e) + \omega C R R_a R_e]^2 \quad (6)$$

and $B^2 = [R_e(1 - \omega^2 LC) + R]^7 + [\omega L + \omega C R R_e]^2$ (7)

Now A^2 reduces to

$$R_a^2 R_e^2 \left[(R^2 + \omega^2 L^2)\left(\frac{1}{R_e} + \frac{1}{R_a}\right)^2 + 2R\left(\frac{1}{R_e} + \frac{1}{R_a}\right) + (1 - \omega^2 LC)^2 + \omega^2 C^2 R^2 \right] \quad (8)$$

and the corresponding numerator for Z^2 is

$$R_e^2[R^2 + \omega^2 L^2] \quad .. \quad .. \quad (9)$$

and if we neglect R^2 by comparison with $\omega^2 L^2$,

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then

$$\frac{Z'^2}{Z^2}=\frac{1}{\eta^2}=R_a^2\left[\left(\frac{1}{R_e}+\frac{1}{R_a}\right)^2+\frac{2R}{\omega^2L^2}\left(\frac{1}{R_e}+\frac{1}{R_a}\right)+\frac{(1-\omega^2LC)^2}{\omega^2L^2}+\frac{C^2}{L^2}R^2\right] \quad (10)$$

$$=\left(\frac{R_a}{R_e}+1\right)^2+\frac{2RR_a}{\omega^2L^2}\left(\frac{R_a}{R_e}+1\right)+\frac{R_a^2}{\omega^2L^2}(1-\omega^2LC)^2+\frac{C^2}{L^2}R^2R_a^2 \quad (11)$$

now let $\omega_0^2=\frac{1}{LC}$, and $\omega_0L=\frac{1}{\omega_0C}=X_0$,

also let $\frac{\omega}{\omega_0}=p$, so that $\omega^2LC=p^2$,

$$\omega L=pX_0,\ \omega C=\frac{p}{X_0},\ \frac{C}{L}=\frac{1}{X_0^2},$$

and lastly, let $\frac{R}{\omega L}=\psi$ and $\frac{R_a}{\omega L}=m$,

then

$$\frac{1}{\eta^2}=\left(\frac{R_a}{R_e}+1\right)^2+\frac{2m\psi}{p^2}\left(\frac{R_a}{R_e}+1\right)+m^2\left(\frac{1}{p}-p\right)^2+m^2\psi^2 \quad (12)$$

Now it will be noticed that of the two terms in p, the second is symmetrical in p and $1/p$, while the first is not, thus the "resonance curve" obtained by plotting η against p is asymmetrical. For our purpose, however, a mean value of η for p and $1/p$ is useful, and the equation is much simplified by substituting 1 for p in the first term. It may be noted that the resulting error is quite negligible for all values of p that are important. Making this substitution, (12) reduces to

$$\frac{1}{\eta^2}=\left[\frac{R_a}{R_e}+1+m\psi\right]^2+\left[m\left(\frac{1}{p}-p\right)\right]^2 \quad (13)$$

as stated in the body of the article.

APPENDIX II.

Derivation of Fig. 6.

This is a simple graph with logarithmic scales, to solve the equation

$$r=\frac{q}{f}=\frac{q\lambda}{3\times10^8} \quad .. \quad .. \quad (14)$$

where $r=p-1$. The vertical scale is, of course logarithmic in r and not in p.

Derivation of Fig. 9.

Since

$$m=\frac{R_a}{X_0}=R_a\omega C \quad .. \quad .. \quad (15)$$

$$\frac{C}{m}=\frac{1}{2\pi fR_a}=\frac{\lambda}{6\pi R_a\times10^8} \quad .. \quad (16)$$

and Fig. 9 is a logarithmic scale graph to solve this.

Measuring Small Changes of Anode Current. [R384·6

In many uses of the valve for radio measurement we are interested, not in the steady current in the anode circuit, but in small changes of that current due to a voltage applied to the grid as the result of some phenomenon under observation. As a particular case may be quoted the drop of anode current on rectification—a change which is frequently utilised in laboratory measurements either with locally assembled gear or in the Moullin H.F. voltmeter arrangement.

In the former case the high value of the steady anode current (relative to the very small changes to be observed) is sometimes inconvenient, especially if a multi-range instrument is available with a scale value suitable for the small changes, but much too sensitive for the steady current.

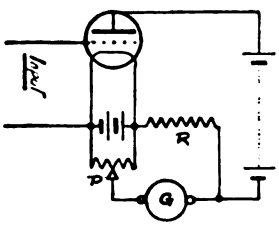

Fig. 1.

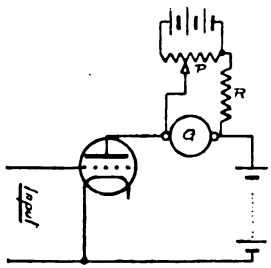

Fig. 2.

Ordinary methods of shunting are inadmissible since they simply reduce the sensitivity of the instrument, and we are compelled to look for an arrangement which balances out the relatively large steady current in the sensitive galvanometer or microammeter, while still leaving it responsive to the small changes.

A very simple arrangement to give this effect has been shown by Moullin and Turner.* It is illustrated in Fig. 1, where it will be seen that the galvanometer is shunted by a high resistance R and that the potentiometer P can be set to give a current through the GR circuit in the opposite direction to the current already traversing the galvanometer due to its position in the anode circuit. The potentiometer can thus be used to set to zero the galvanometer or microammeter, which will then show the change under observation (correction being made for the shunting effect of R).

This arrangement is convenient in that it

* *Journal I.E.E.* Vol. 60, No. 310, June, 1922.

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utilises the already existing filament battery as a source of the balancing current, but it involves non-commoning of the filament

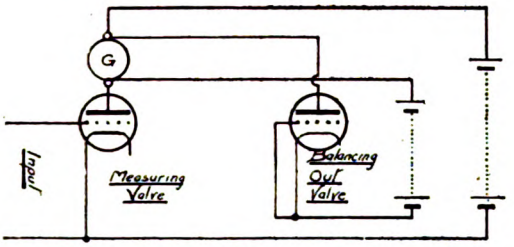

Fig. 3.

and anode batteries. In some cases where this commoning already exists and cannot conveniently be broken, it may be more convenient to use a separate battery with the potentiometer, as shown in Fig. 2. This is exactly similar in principle to the arrangement in Fig. 1.

Another convenient arrangement is that of a balancing out or "backing-off" valve, as shown in Fig. 3. The filament of the balancing out valve is then adjusted to zero the galvanometer. This has the advantage of effectively shunting the galvanometer (in so far as its position in the measuring valve is concerned) by a resistance which is the anode impedance of the balancing valve and will therefore be so large compared with the resistance of the galvanometer that its shunting effect can be ignored. J. F. H.

Meters for Valve Transmitters. [R 384

THERE are probably quite a number of transmitting amateurs who, for reasons of economy, have failed to invest in the milliammeter and H.T. voltmeter necessary for determining the input power, and it is proposed to show how an ordinary moving-coil ammeter may be modified to serve the purposes of both these instruments.

The moving-coil type ammeter, reading up to about 20 amps, is quite cheap, and to convert it into a milliammeter it is only necessary to disconnect the low resistance shunted across the winding. To calibrate it the meter should be joined in series with a high resistance (such as a high resistance ear-piece) and a battery of 6 volts. The current passing through the circuit is found from Ohm's law. If the needle points to, say, 4 amps, when the actual current is 6 milliamps, it may be assumed that 10 amps would indicate 15 milliamps, and so on.

The next step is to use the meter for the measurement of H.T. up to about a 1 000 volts. In this case a resistance of something in the neighbourhood of 50 000 ohms is required. The anode resistance used in the receivers is altogether out of the question; similarly, to wind one by hand is beyond the patience of most of us. This leaves the liquid resistance, which is quite suitable if it is not overworked.

A glass tube about 5 inches long and ½ inch diameter should be fitted with two corks, through which pass two thick wires to act as electrodes. The tube must be nearly filled with distilled water and joined in series with the meter and a source of H.T. of about 200 volts' pressure. Dilute sulphuric acid should then be admitted into the water, drop by drop, until the meter registers about a fifth of the highest desired reading; that is to say, until the applied voltage is 200, when the meter is required finally to 1 000 volts. The same method of calibration as that used previously may also be employed here, but, of course, the instrument may be calibrated against standard meters if they are available.

The tube containing the dilute acid solution should be placed in a vertical

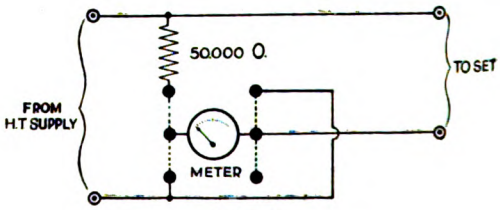

Fig. 1.

position, and the upper cork should have a vent to allow the gases caused by electrolysis to escape.

If this meter, now a combined milliammeter and H.T. voltmeter, is joined up with the resistance and a D.P.D.T. switch to the circuit shown in Fig. 1, the change from one instrument to the other will be a simple matter and the input to the set may be determined easily and quickly. S. K. L.

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Distortion in Wireless Telephony, and Related Applications of the Cathode Ray Oscillograph.

By E. K. Sandeman and N. Kipping. **[R135-R388**

Part II.

APPLICATION OF THE CATHODE RAY OSCILLOGRAPH.

A. Introductory Remarks.

SINCE the Cathode Ray Oscillograph has only recently reached the stage of development where it is within easy reach of the ordinary research laboratory, a good deal yet remains to be learnt of the uses to which it can be applied. There are, however, several cases in which it has been of service where other means of investigation have proved either cumbersome or totally inadequate.

Amongst the latter cases may be included the study of atmospherics, of dynamic valve characteristics and of the process of modulation.

It has been found very useful also in comparison of frequencies with great accuracy and the plotting of circuit characteristics generally.

Perhaps it should here be remarked that the great advantages of the Cathode Ray Oscillograph over other types are that, being free from inertia, it is capable of dealing with radio frequencies ; that it plots in rectangular co-ordinates the characteristic under examination ; and that the curves plotted may be visually examined, without the necessity for recording photographically.

For the benefit of those who are not familiar with the function of the Cathode Ray Oscillograph, a description was included in last month's issue.

In oscillographic investigations, it frequently happens that data are required of the way in which oscillating currents or voltages vary with time, rather than of the way in which they vary with some other dependent variable. It is consequently necessary to establish a means of procuring a time scale with the cathode ray oscillograph. The method which the authors have used is described in Appendix II.

B. Application.

The Study of Atmospherics.—This matter has been the special study of the Radio Research Board, established under the Department of Scientific and Industrial

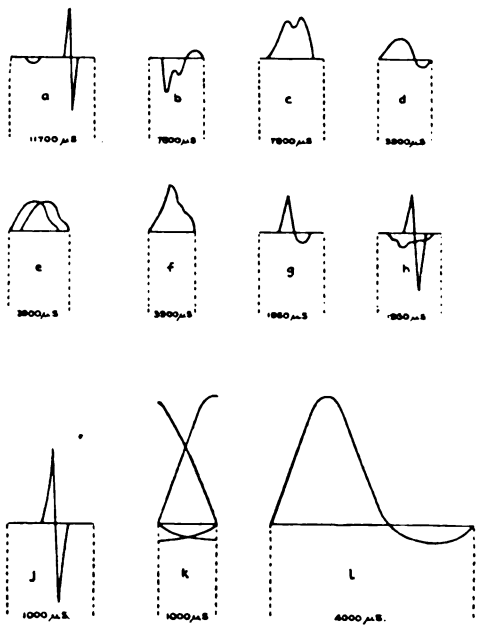

Fig. 13.

Research, by whose kind permission we are able to publish Fig. 13. In this figure are seen direct tracings from the oscillograph screen of some selected samples from the wave forms of atmospherics. These strays were observed visually on the oscillograph screen, and delineated by the Radio Research Board with the help of a linear time base developed for the purpose by Appleton, Herd and Watt, who have been responsible for this important investigation.

The duration of the forms traced in the figure is shown below each one in micro-

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seconds (μs). The duration is, of course, known from the frequency of operation at which the time-base was working.

The forms shown are typical. Form *k* is an excellent example of the use of the linear time base, for in this figure the complete form lasted four times the duration of the base. The known linearity of the base permits one to reconstruct the form on a continuous base, and this is done in 1.

Dynamic Valve Characteristics.—With such an arrangement as that shown in Fig. 14, the oscillograph may be employed for the plotting

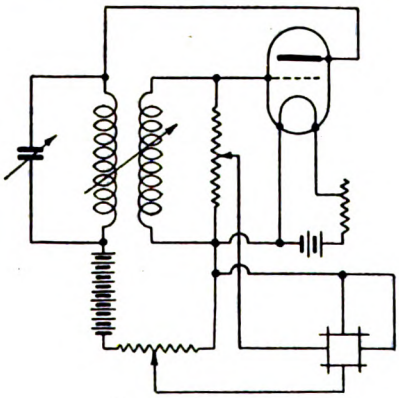


Fig. 14.

of dynamic valve characteristics. It will be seen that the deflecting plates are so connected that the curve charted will represent the relation between variations in grid potential and anode current.

Assuming that the grid is always maintained sufficiently negative with respect to the filament to prevent any convection current flowing between filament and grid, then with oscillations sufficiently feeble to ensure that the valve is working on the straight part of its characteristic, approximately simple oscillation is obtained. By a simple oscillation is meant an oscillation in which all the A.C. currents and voltages associated with the circuit are sinusoidal waves of the same frequency. This condition involves that all the impedances of the circuit should be linear—a condition never obtainable in practice. It is, however, possible to approximate very closely to this requirement, when oscillation is very feeble.

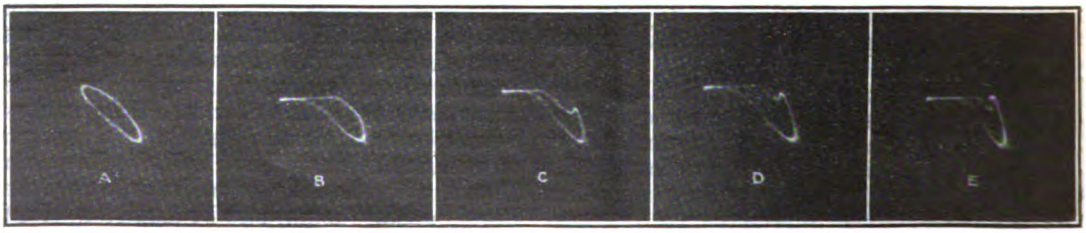
The above conditions for simple oscillation do not necessarily mean that the anode current and grid voltage are in phase; the condition for phase coincidence is that the inductances of the plate and grid coils shall be resistanceless, for if they are not a phase difference between the anode current and grid voltage is introduced. It follows that, in all practical cases, this phase difference exists.

When plotting dynamic valve characteristics of anode current against grid volts, it is therefore to be expected that the figure will not take the form of a straight line, but of an ellipse, whose dimensions will depend upon the amount of phase difference existing.

(It should be remembered that if two equal sine waves are plotted together in rectangular co-ordinates on equal scales, they produce a straight line sloping at 45° if they are in phase or 180° out of phase, and a circle if they are 90° out of phase. Intermediate phase relations produce some sort of ellipse.)

Fig. 15A shows the dynamic characteristics of an oscillator operating in approximately the simple manner described. The phase difference mentioned may be noticed in this figure.

In considering the characteristics to be expected when oscillations are more violent, it is convenient to neglect for a moment the



Eg
V Ip

Fig. 15. The direction of the plate current (Ip) deflection in these photographs is the reverse of that usually shown in figures. This was done to simplify circuit arrangements, but of course makes no difference to the results.

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question of phase difference. The ellipse of Fig. 15A might then become the line *BC* in Fig. 16. On increasing the violence of the oscillations, this curve would first stretch out towards *A* and *D*, and subsequently might extend to *A* and *E*. The flattening of the curve towards *A* is due to the zero limitation of the anode current, while the flattening and dropping of the curve on the portion *CDE* is due to the dropping of the anode voltage and possibly, in some measure, to the saturation limitation of anode current. The oscillations may in some cases reach such violence that the anode actually becomes negative, and for the second time in the cycle no anode current flows. This state is a form of "impulse excitation." It is well to bear in mind that the anode potential varies approximately sinusoidally in an efficient oscillating circuit, no matter what the shape of the anode current, since the potential of the anode is governed by the potential across the oscillatory circuit.

The drop over the section *DE* of Fig. 16 is probably augmented by the flowing of convection grid current, which increases as the anode current decreases. This reduces

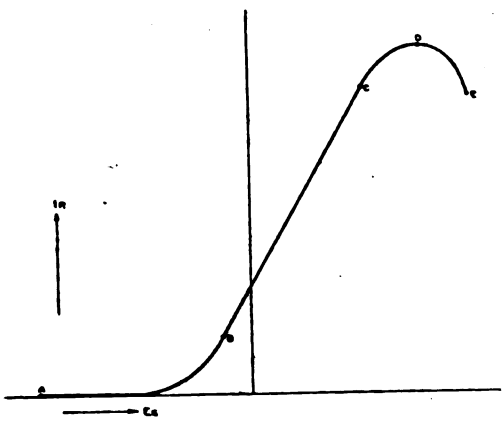

Fig. 16.

the potential of the grid, so that the anode current becomes still further decreased.

These effects combine to produce Fig. 15, C, D and E in which the oscillations are becoming successively more violent. These figures, of course, suffer the same phase displacement as Fig. 15A. In Fig. 15E, conditions have combined to cause the anode current to reach zero twice in the cycle.

This may perhaps indicate the way in which the dynamic valve characteristic may

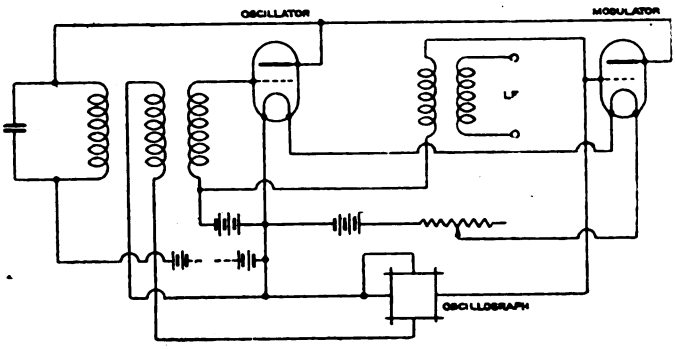

Fig. 17.

be used to examine the function of an oscillatory circuit. It is, of course, entirely practicable to observe changes in the shape of the characteristic while circuit adjustments are being made.

Determination of Percentage Modulation.—The cathode ray oscillograph may be used for the simultaneous study of both the percentage modulation and the quality reproduction characteristics of a radio transmitting set.

In Fig. 17 is shown a type of anode modulation circuit, whose working is so inefficient as to emphasise those points which the oscillographic records obtained will show up. The circuit depends for its modulation on a change in resistance of the modulator valve, which is a shunt on the carrier oscillatory circuit. These resistance variations are brought about by the audio frequency wave, when the modulator valve is working on the curved part of its characteristic. Were it working on the straight part of its characteristic, the oscillatory circuit would only be shunted by the characteristic impedance of the modulator valve, the audio frequency wave then having no modulating effect.

In order to make it possible for modulation to be so complete as to reduce the carrier oscillations to zero amplitude (for peak values of the audio frequency), it is necessary to devise coupling arrangements in the carrier oscillator which are so loose that zero amplitude may be reached when the oscillator

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is shunted by the minimum obtainable shunt resistance—that is to say, by the characteristic impedance of the modulator tube.

This unstable working of the oscillator has the effect of making the oscillations slow in building up and, to some extent, in dying down. There is in fact a critical value for the damping resistance at which the oscillations build up very rapidly, and by no means proportionally with the damping resistance—that is to say, with the instantaneous voltage applied to the modulator grid. This, of course, produces inherent distortion. Another possible source of trouble is that the audio frequency potential may exceed the limits of the curved part of the modulator characteristic in either direction, which is analogous to the ordinary case of overloading.

The oscillograph is connected to this circuit in such a manner that in one direction it indicates the audio frequency voltage, and at right angles the radio frequency output. Were modulation complete and without distortion, it is clear that a figure of the shape of an isosceles triangle would be produced, as shown in Fig. 18A; the base of this triangle would represent the maximum radio frequency amplitude, and its height the audio frequency amplitude. If modulation were incomplete, the triangle would have no true apex, and would become a trapezium in which the length of the shorter parallel side would indicate the minimum radio frequency amplitude. Then if the longer parallel side be called (a), and the shorter (b), the expression :—

$$\frac{a-b}{a} \times 100$$

will give a measure of the percentage modulation obtained. Modulation of 100 per cent. will then produce Fig. 18A.

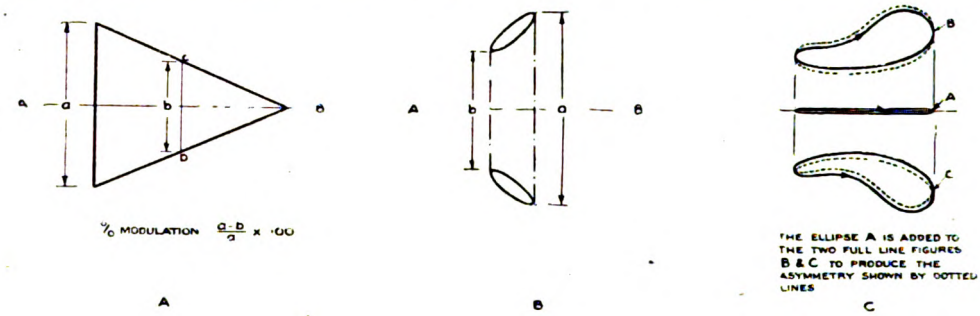

Fig. 18.

The photographs shown in Fig. 19, showing figures produced from the circuit of Fig. 17, do not in any case show exactly the trapezium or triangular form which should be theoretically obtainable. In Fig. 19A, a symmetrical figure of general trapezium shape is bounded on the unparallel sides by two ellipses instead of by two straight lines. It will be seen from Fig. 17 that the connections made to the oscillograph are of necessity from opposite sides of the modulator valve. The presence of inductance and capacity in the input and output circuits of this valve are responsible for a phase difference between the input

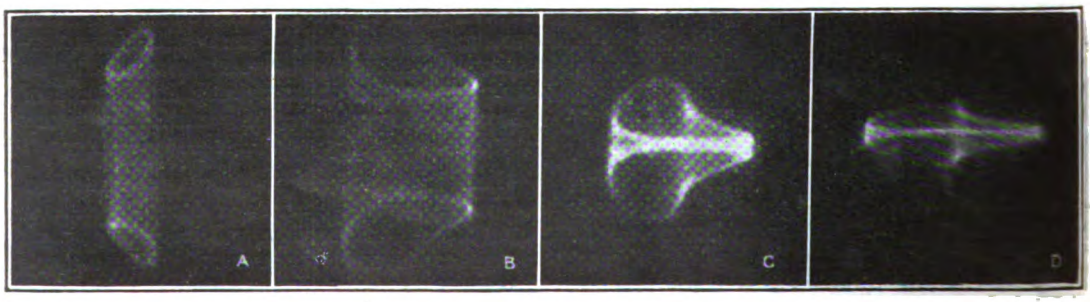

Fig. 19.

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audio frequency and the envelope of the output radio frequency wave. This phase difference causes the elliptical boundaries to the photograph of Fig. 19A. It is clear that the maximum and minimum amplitudes of the radio frequency wave are, in this case, represented by the lengths *a* and *b* respectively in Fig. 18B.

In Fig. 19B and C, however, the boundaries to the trapezia do not take either straight line or elliptical form.

Their shape is the result of the inherent distortion of the system which has already been mentioned. In Fig. 19B, the percentage modulation is about 60 per cent., while in Fig. 19C it is practically 100 per cent. In Fig. 19D, the radio frequency has zero amplitude for a large portion of the cycle, so that over-modulation has occurred. The critical building up of the carrier oscillator is marked in Fig. 19D, in which the envelope of the figure shows a steep slope about the centre, just when the oscillator finally builds up to its maximum amplitude.

With more efficient types of modulation than that chosen above, it might be possible to avoid any phase difference between the audio frequency and the changes in radio frequency amplitude, so that the boundaries to the oscillographic figures produced would be single lines, rather than types of ellipses. Also if there were no distortion these boundaries would be straight lines, so that the shape of the envelope of the figures will in all cases give a measure of the quality reproduction characteristics of the system.

It will be appreciated that audio frequency distortion is extremely likely to occur if mean modulation is allowed to exceed a small percentage, as peak values of voltages will cause over modulation. It is as a rule impracticable to modulate so weakly, as power output would be correspondingly reduced. We should repeat that the great variations in intensity which have to be dealt with in average broadcasting, coupled with the need for high power output, make it difficult to select a degree of modulation which is satisfactory from both standpoints.

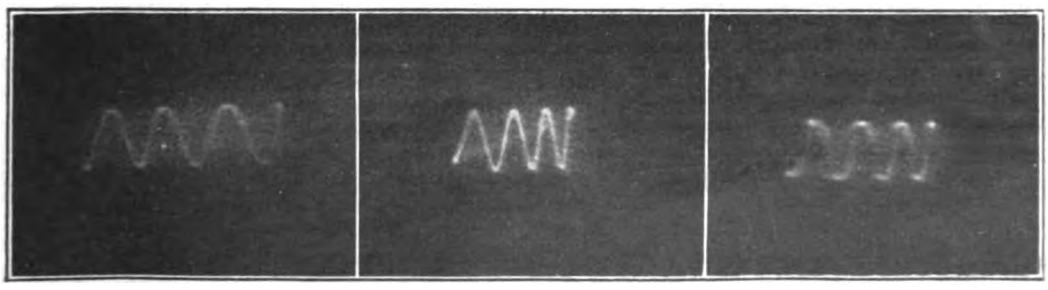
It will be noticed that Fig. 19A, B, C and D are more or less asymmetric about a horizontal axis.

It has been suggested by Mr. A. D. Blumlein that this is caused by the audio frequency variations in anode current flowing in the anode circuit of the oscillator, and from there being induced into the coil used for obtaining the vertical deflection on the oscillograph. This deflection will be nearly 90° apart in phase from the voltage producing the horizontal deflection, and considered apart from the carrier frequency deflection would produce an ellipse. This ellipse then becomes added to the normal deflection which would be obtained were this effect not present, in the manner shown in Fig. 18C.

General Investigation of Asymmetric Distortion.—The introduction in, for example, an amplifier of frequencies not present in the input wave, may be detected by a simple plotting, and subsequent comparison of input and output waves.

The time base which the authors have used for wave-form examination is described in Appendix II.

For a thorough examination of a circuit for asymmetric distortion, it would be advisable to make such a comparison of input and output waves throughout a range of frequencies where the input is a sine wave. A potentiometer arrangement will in many cases enable an output wave to be brought to the same dimensions on the oscillograph screen, as the input wave, so that comparison of the two is facilitated. This was done in the case of Fig. 20, where A was the



A B C

Fig. 20.

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input to an amplifier, B the output where A was about 0.05 milliamperes, and C the output where A was about 2.0 milliamperes. The distortion due to the overloading of the amplifier in the case of C is obvious. The frequency of the wave in these cases was about 10 000 p.p.s.

A slight unevenness of the time scale will be noticed in Fig. 20, especially in B and D The reason for this, and a means of avoiding it, are mentioned in Appendix II. The figure shows, however, that absolute linearity is unnecessary when only a comparison of waves is required, as in this case, and the refinement of more complete linearity in time scale may be omitted.

The examination of the wave-form in this manner may be made in any part of the circuit concerned, and a source of trouble may often be tracked down by progressive examinations through the apparatus. The nature of the wave distortion found will frequently suggest a clue as to the source of the trouble. For example, a wrong grid bias in an amplifier might be responsible for flattening the top of a wave, the peak voltage value being such as to extend over the limits of the characteristic of the amplifying valve. Overloading of the valve will also tend to produce a second harmonic, especially when grid current is permitted to flow. Again, transformers are a fruitful source of odd harmonics, frequently producing the characteristically pointed wave caused by the presence of a third harmonic.

It will in general probably be found that overloading is the most usual source of trouble to be found in amplifying circuits. The output wave form may in such cases be observed at the same time as adjustments of the damping or coupling, etc., are made, so that the maximum or minimum safe values, as the case may be, may be quickly determined.

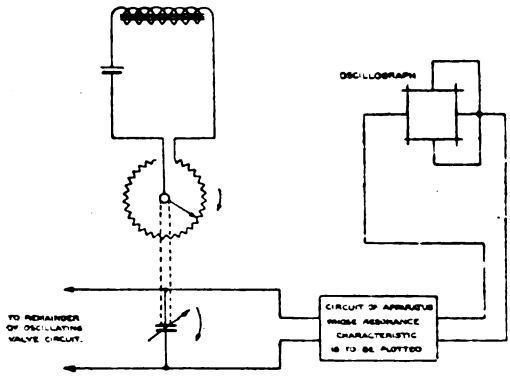

Fig. 21.

Frequency Resonance Curves.—The resonance characteristics of circuits have been studied by the arrangement shown in Fig. 21.

In this arrangement alternating current is supplied to the circuit to be studied, the potential difference across which is applied to that pair of the oscillograph plates which controls vertical deflection. The frequency of the A.C. is controlled by a variable condenser rotated synchronously with a circular potentiometer, the latter being arranged to control the current passing through an iron core induction coil. The coil is placed in such a position adjacent to the oscillograph that the varying field exerted by it, causing a correspondingly varying flux in the iron core, deflects the ray horizontally. The figure produced is of the type shown in Fig. 21*a*. The amplitude of the oscillations in the circuit being studied clearly increases as the resonance frequency is reached, and the range of frequencies covered by one revolution of the controlling condenser being known, an accurate idea may be gained of the resonance frequency found. As the condenser and rheostat are rotated synchronously, the vertical and horizontal deflections of the ray are also synchronous, so that a steady picture is obtained.

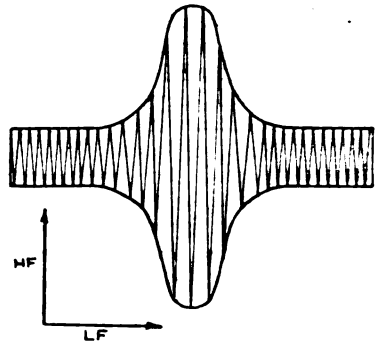

Fig. 21*a*.

This arrangement may, of course, be used for the study of amplifying circuits, or for mechanical parts, such as loud speakers or receivers.

Some other Related Applications.—Two simple methods of comparing frequencies with great accuracy depend upon the use of the cathode ray oscillograph.

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In the first, a source of known frequency is applied to one pair of deflecting plates, and the uncalibrated source to the other pair of plates. If the relation in frequency is 1 : 1, the figure produced is a straight line or a circle, or a form of ellipse depending on the phase relation between the two sources. If the relation is not exact, the figure appears to revolve, going from the straight line condition to the circular condition through the various stages of an ellipse: the figure revolves once per second if the two frequencies differ by one cycle per second. If the frequency relation is some other simple ratio, the figure obtained is a form of the appropriate Lissajou figure, which again revolves when the relation is inexact. As very slow movement can be seen, it is possible to adjust the unknown frequency with great accuracy.

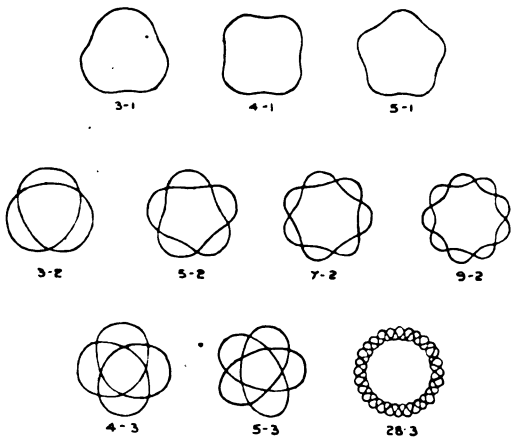

Fig. 23.

The disadvantage of this method is that the figures become complicated and difficult to recognise when the frequency relation is complicated. The second method, due to Mr. D. Dye, of the National Physical Laboratory, does not suffer to the same extent from this trouble, and is, apart from other considerations, of interest because it makes use of the fact that the sensitivity of the oscillograph increases as the anode potential decreases.

A circle is produced on the screen by means of the circuit shown in Fig. 22, in which $R = 1/\omega C$, the source of A.C. used for obtaining the circle being of known frequency.

The source of unknown frequency is connected in series with the anode battery, and has the effect of making the net anode potential vary between limits controlled by its own A.C. voltage. Suppose the fixed anode battery to be V volts, and the A.C. source to vary between $+v$ and $-v$ volts. Then the anode potential varies between $V-v$ and $V+v$ volts. The circular trace on the screen is biggest when the anode potential is $V-v$ volts and smallest when the anode potential is $V+v$ volts. Suppose the frequency of the unknown source to be five times that of the known source, then the diameter of the circle will be at its greatest and at its least each five times per cycle of the known source. If the relation is exact, the figure produced is of a cart-wheel type. This rotates if the relation is inexact. The type of figure produced with various frequency relations is shown in Fig. 23, in which the system will be seen to be quite clear. Even quite complicated relationships may be examined in this way, and the method is of considerable accuracy.

Valve characteristics may be plotted with the cathode ray oscillograph by means of the

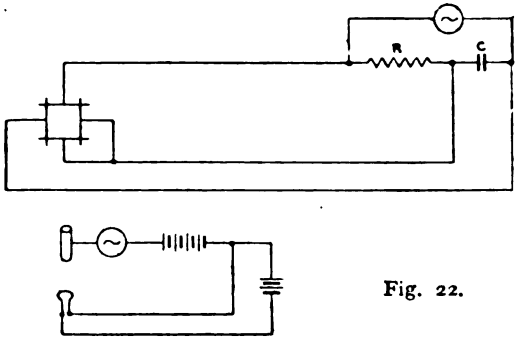

Fig. 22.

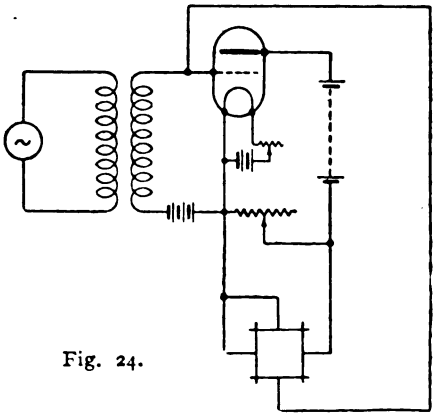
Fig. 24.

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type of circuit shown in Fig. 24. With this arrangement, the horizontal deflection is controlled by the sinusoidal input to the grid of the valve, while the corresponding plate current variations control vertical deflection. The grid bias and applied A.C.

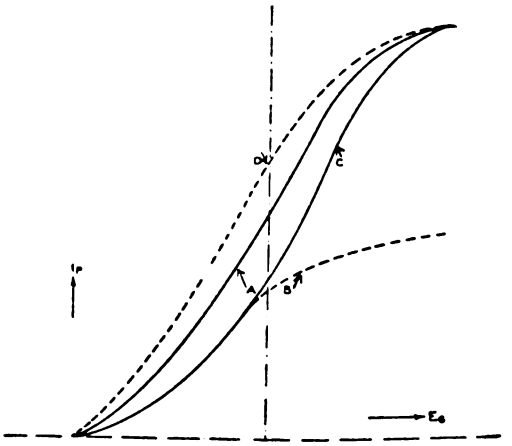

Fig. 25.

potential are adjusted so that the net grid potential at least reaches the zero and saturation limitations of the valve being tested.

The circuit shown is arranged to chart grid voltage-plate current curves, and in Fig. 25 tracings of the type of figure obtained are shown. It is, of course, possible to observe changes in the shape of the curves obtained, when alterations are made to battery voltages and filament current. Thus in Fig. 25, for A the filament current was 1.25 amps and the plate voltage 150 volts. In B, the filament current was reduced to 0.95 amps. In C the plate potential has been reduced to 100 volts, while the filament current remains at 1.25 amps, and in D the plate voltage is 200.

When the characteristics of a number of valves are required, this method is extremely quick and useful, but for a single tube, of course, the time taken in setting up the apparatus would probably not justify any departure from the slower point by point method.

Conclusion.—In concluding, the authors would like to thank Messrs. J. Collard and P.R. Thomas for their very able assistance in photographing the oscillographic records. It will probably be of interest to record that most of the photographs were taken with an exposure of one minute, with a lens operating at f/4.5 and using plates of speed 700 H & D. Fig. 20A, however, was exposed for only fifteen seconds, the other conditions remaining the same.

Photographs of the cathode ray oscillograph are published by the courtesy of the Western Electric Co.

APPENDIX II.

A Linear Time-base for Examining Wave Forms with the Cathode Ray Oscillograph.

Wave forms are most familiar when plotted on a linear time-base, and the provision of a means of obtaining this is a valuable adjunct to any oscillograph. The vibrating strip type of oscillograph usually employs the rather cumbersome rotating mirror device for providing a linear time scale for visual working, while a falling or projected photographic plate is used for photographic recording. The latter is, of course, impossible with the cathode ray oscillograph, as the fluorescent spot is insufficiently intense to permit instantaneous photography. The rotating mirror could be used, but is by no means an ideal system, as well as having a rather low limit in the speed at which it can be worked satisfactorily.

The cathode ray oscillograph, however, permits the use of an entirely different type of time-base—one brought about by means of suitable potential variations across one pair of the deflecting plates.

An ordinary sine wave connected in this way would, of course, give figures in the form of ellipses, with various superposed loops, when plotted against the wave to be examined, but for most work a subsequent mathematical translation from this sinusoidal base to a linear base would be necessary.

The authors have used the time-base, whose method of production is illustrated in Fig. 26.

When the battery is switched on in this circuit, the neon lamp may be said to be on open circuit. The condenser C in parallel with the neon lamp charges up through the high resistance R until the discharge potential of the lamp is reached, and at that moment the condenser discharges through the lamp until the failing potential of the lamp is reached, after which the cycle of operations is repeated. (The neon lamp, being a discharge device, "strikes" and "fails" at critical potentials, approximately 170 and 145 volts respectively.) Thus the lamp "blinks" at a frequency governed by the values of the battery potential B, the resistance R, and the condenser C. The condenser charges, and therefore the lamp blinks at intervals of time t according to the expression—

$$e = B\,(1 - \varepsilon^{-t/RC})$$

where e is the striking potential of the lamp. Now the current flowing through the resistance R is the condenser charge current, which in this circuit follows a slightly curved saw-tooth wave shape. The period of discharge of the condenser is very short, so that by connecting one pair of the oscillograph deflecting

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plates across a convenient portion of the resistance *R*, the spot is made to travel slowly across the screen, returning almost instantaneously, and repeating the movement at a frequency which may be controlled. Potential variations arranged to deflect the spot at right angles to the time-base are therefore spread out on a time-base which, although not exactly linear, is for comparative and many other purposes of great value. Far greater linearity may be obtained by substituting a saturated diode for the resistance *R*, for under these conditions it is clear that the current flowing through the diode is constant, and therefore that the quantity of electricity in the condenser becomes a linear function of time. Consequently, the potential across the diode becomes a linear function of time, and is made use of for obtaining the time-base for the oscillograph. The only requirement for this device to produce a truly linear time-base is that the current flowing through the diode must always be sufficient to saturate it.

Normally, it is found to be extremely quick and simple to control the frequency by adjusting *C*, but alterations in *R*, or the filament current of the diode, may in some cases be found more convenient. It is usually best to arrange the frequency of the time-base deflection to be one-third or one-fourth of the frequency of the second deflection so that three or four complete waves of the second deflection are traced out before the failing potential of the neon lamp is reached and the figure is retraced. The photographs of Fig. 20 show how accurately it is possible to tune the frequency of the neon lamp, as in these the figures were kept stationary for periods of one minute.

The device works satisfactorily until the charge time of the condenser is equal to or less than the discharge time. This occurs at about 6 000 p.p.s. and as wave forms may still be examined when, say, 10 complete waves are traced on the screen the system is good for the examination of waves of frequencies up to about 60 000 p.p.s.

In Fig. 20 (B & C), the circuit shown in Fig. 26 was used for the time-base, while in Fig. 20A the saturated diode arrangement was used. The latter will be seen to be far more linear than the former, although complete linearity is seen to be unnecessary for comparative purposes. Indeed, except where actual measurement of harmonics, etc., is to be attempted, complete linearity is of no particular use, provided the crowding of the time-base is as small as that obtained in this device.

BIBLIOGRAPHY.

Acoustics.

"Collected Papers on Acoustics." By W. C. Sabine, 1922.

"Acoustics of Buildings." By F. R. Watson.

"The Acoustics of Room Reverberations." By E. A. Eckhardt.—*Journ. Franklin Inst.*, p. 799, June, 1923.

Atmospherics.

"Observations on Atmospherics." By R. A. W. Watt.—*Wireless World and Radio Rev.* 12, pp. 601-612, August 1, 1923; pp. 636-637, August 8, 1923; *Elec. Rev.* 93, pp. 266-7, August 17, 1923.

"Directional Observations of Atmospherics." By R. A. W. Watt.—*Phil. Mag.* 45, pp. 1010-1026, May, 1923; *Roy. Soc. Proc.* 102, pp. 460-478, Jan. 1, 1923.

"On the Nature of Atmospherics." By R. A. W. Watt.—*Roy. Soc. Proc.* 103, pp. 84-102, April 2, 1923.

"The Simultaneous Origin of Atmospheric Disturbances." By M. Baumler.—*Jahrb. d. drahtlos. Tele.* 22, pp. 2-8, July, 1923.

"The Origin of Atmospherics." By R. A. W. Watt.—*Nature* 110, pp. 680-1, November 18, 1922.

"Energy of Atmospherics." By T. L. Eckersley.—*Electrician* 93, pp. 150-151 and 155, August 8, 1924.

"Atmospherics." By L. W. Austin.—*Nat. Res. Council Bulletin* 7, No. 41, pp. 127-130, *Washington*, 1924. *Monthly Weather Rev.* 52, pp. 220-221, April, 1924.

"Atmospherics and their Effect on Wireless Receivers." By E. B. Moullin, M.A.—*Journal I.E.E.*, p. 353, April, 1924.

Cathode Ray Oscillograph.

Phys. Soc. Proc. 35, pp. 109-124, November, 1922, and p. 127, November, 1922.

"A Low Voltage Cathode Ray Oscillograph." By J. B. Johnson.—*Journal of Optical Soc. of America*, September, 1922.

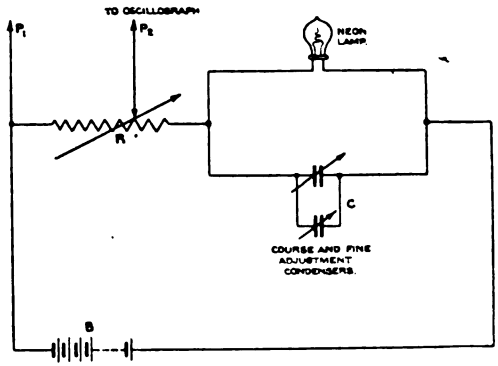

Fig. 26.

"A Practical Demonstration of Some Applications of the Cathode Ray Oscillograph." By N. Kipping.—*Wireless World and Radio Rev.*

Distortion.

"Transmission Maintenance of Telephone Systems." By P. E. Erikson and R. A. Mack.—*Journal I.E.E.*, August, 1924.

"Faithful Reproduction in Radio Telephony." By L. C. Pocock.—*Journal I.E.E.*, September, 1921.

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"The Development of Simultaneous Broadcasting." By E. K. Sandeman.—*Wireless World and Radio Rev.*, p. 521, June 23, 1924.

Electromagnetic Screening.

"Electromagnetic Screening." By R. W. Watt and J. F. Herd.—*Wireless World and Radio Rev.*, pp. 532-539. January 1, 1923.

General.

"Problems in Telephony Solved and Unsolved." By Prof. J. A. Fleming.—*Journal I.E.E.*, June, 1923.

"Electrical Vibration Instruments." By A. E. Kennelly.

Interference.

"Trans-Oceanic Wireless Telephony." By H. W. Nicholls.—*Journal I.E.E.*, July, 1923.

"Auditory Masking of One Pure Tone by Another." By R. L. Wegel and C. E. Lane.—*Phys. Rev.*, February, 1924.

"Elimination of Interference."—*Wireless World and Radio Rev.* 12, pp. 693-695, August 22, 1923.

Loud Speakers.

"Zur Theorie des Lautsprechers."—*Wissenschaftlichen Veroffentlichungen aus den Siemens Konzern*, Vol. III., p. 62.

"Discussion on 'Loud Speakers for Wireless and other Purposes' with Introductory Papers"—*Journal I.E.E.*, p. 265, March, 1924.

"Loud Speakers." By E. K. Sandeman.—*Wireless World and Radio Rev.*, p. 225, May 21, 1924.

Measurements.

"Radio Instruments and Measurements."—*Bureau of Standards Circular No.* 74.

Modulation and Detection.

Proc. Inst. Radio Engineers, 1919.

Telephone Receivers.

"Theoretical and Experimental Study of Telephone Receivers." By A. E. Kennelly.—*P.O.E.E. Journal* 16, Part 2, July, 1923.

Telephone Transmitters.

"The Sensitivity and Precision of the Electrostatic Transmitter for Measuring Sound Intensities." By E. C. Wente.—*Phys. Rev.*, Vol. XIX., No. 5, p. 498.

Vacuum Tubes.

"On the Form of Free Triode Vibrations." By E. V. Appleton and B. van der Pol.—*Phil. Mag.*, August, 1921.

"Experimental Determination of the Fundamental Dynamic Characteristics of a Triode." By Eijiro Takagishi.—*Proc. Inst. of Radio Engineers*, pp. 609-622, October, 1924.

The Sterling Anode Reaction Unit. [R382·5

WE have recently tested one of the above components manufactured by the Sterling Telephone & Electric Co., Ltd., of 210-212, Tottenham Court Road, W.1.

The unit provides a simple means of coupling H.F. valves by the tuned anode method, with the introduction of reaction; if desired, it could also be used as the aerial coil, with reaction. A knob controls the reaction coil, which is mounted at an angle of 45 degrees to the spindle so that a rotation of 180 degrees of the knob moves the coil from its position of maximum to minimum coupling.

The device is really in two parts, the knob and adapter (which are permanently mounted in the set) and the actual tuning units which are interchangeable, so that various wave-length ranges may be covered.

Ingenious construction is coupled with electrical efficiency in this unit. It is also most compact.

The two coils in the tuning unit are of silk-covered copper wire wound in wave form and waxed, and mounted on formers of insulating material.

A moulded cover is fitted over the coil unit so that the coils are protected when in use. Connections between the coil unit and adapter are made by means of four spring clips, which also serve to fix the two portions of the component together.

We measured the self-inductance of each coil of the unit sent to us, which is intended for the lower broadcast range.

Neglecting the self-capacity, the inductance of the anode coil was 332μH and that of the reaction coil 116μH.

These values correspond to standard plug-in coils of approximately 75 and 50 turns respectively. The maximum coupling coefficient was 46 per cent. and the minimum 0.5 per cent. Thus, though there is no negative coupling, the positive coupling can be reduced almost to zero.

We noticed that the coupling of this unit with external coils was very small, which is a good point, since stray couplings, particularly in an H.F. amplifier, are to be avoided.

The units are made in eight sizes, lettered from A to H; that tested was D, with a nominal range of 280-550 metres when used in a tuned anode circuit with a .000 25μF condenser in parallel.

The adapter with one coil unit costs £1, and extra coil units are obtainable, price 12s. 6d.

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Filters:

A Supplementary Note. [R386

By P. K. Turner.

It has been pointed out to the writer that in his recent notes on filters,[1] he omitted to deal with band filters with regard to controlling the width of the band passed or stopped.

This is an extremely simple matter, and to avoid waste of space will now be dealt with as an extension of the previous article, to which reference should be made for explanation of symbols, etc.

It will be remembered that the curves which gave the "filter impedance" of the filter (*i.e.*, input volts over output current) were drawn in terms of a quantity "s," defined as Z_1/Z_2 (see Fig. 1, reproduced from the original article). It may also be restated that for $s=o$ to $s=-4$, the filter impedance is low, while for $-s>4$ the impedance continually increases. That is, the filter "passes" for $-s<4$ and "stops" for $-s>4$.

The value of s is a function of the frequency. If ω_0, f_0 and λ_0 refer to the frequency for which all the sections of the filter are tuned, then we gave originally for a BAND PASS FILTER

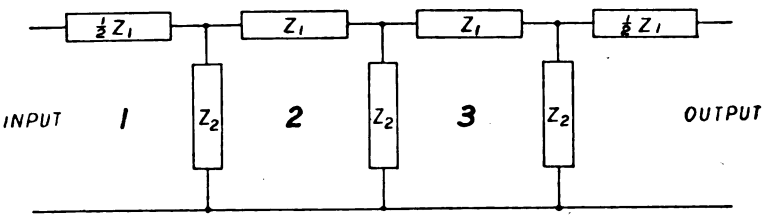


Fig. 1.

The most general type of filter; Z_1 and Z_2 represent impedances of some kind.

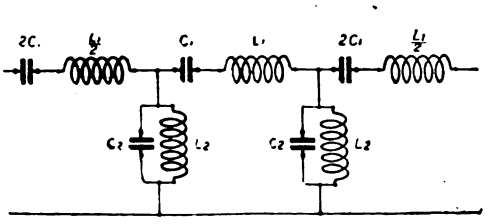
$$s=-\left(\frac{\omega}{\omega_0}-\frac{\omega_0}{\omega}\right)^2=-\left(\frac{f}{f_0}-\frac{f_0}{f}\right)^2=-\left(\frac{\lambda_0}{\lambda}-\frac{\lambda}{\lambda_0}\right)^2 \quad (1)$$

NOTE.— In the original article, the second term was, by a printer's error, shown as $\left(\frac{\omega}{\omega_0}\right)^2$.

and for a BAND STOP FILTER

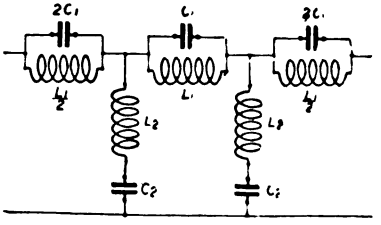
$$s=\frac{-1}{\left(\frac{\omega}{\omega_0}-\frac{\omega_0}{\omega}\right)^2}=\frac{-1}{\left(\frac{f}{f_0}-\frac{f_0}{f}\right)^2}=\frac{-1}{\left(\frac{\lambda_0}{\lambda}-\frac{\lambda}{\lambda_0}\right)^2} \quad (2)$$

[1] P. K. Turner, "Filters," E.W. & W.E., Aug., 1925, p. 673.



Band Pass

Fig. 3a



Band Stop

Fig. 3b

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In arriving at these values, however, a certain assumption was made with regard to the values of coils and condensers to be used. Fig. 2 shows the types of filter being considered, and hitherto we have assumed $C_1 = C_2$ and $L_1 = L_2$. It is by variation here that we control the width of band.

It should be noted first that the "width of band" is quite distinct from the "sharpness of cut." Fig. 3, for example, shows

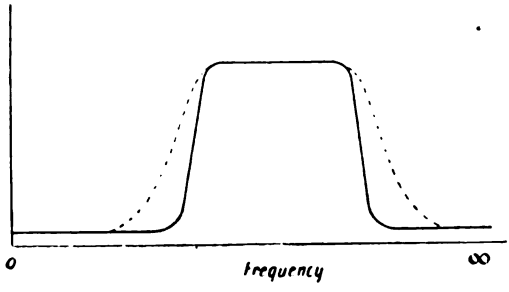

Fig. 3.

the type of curve for two-band pass filters of which the width of band is the same, while the dotted curve shows a less sharp cut-off. How to get any required sharpness was dealt with in the original article.

If now we draw curves of s against f_0/f for the two types of filter already dealt with we get the curves of Fig. 4, from which we see that for the pass filter $-s<4$, *i.e.*, the filter "passes," for any frequencies between .4 times and 2.5 times f_0, while the stop filter "stops" for frequencies between .8 times and 1.25 times f_0, and these proportions are fixed.

But if now we put $L_1 = kL_2$, and $C_1 = \frac{1}{k}C_2$, so that L_1C_1 still equals L_2C_2, then it will be found that the values of s are k times what they were before: in fact we have

BAND PASS

$$s = -k\left(\frac{\omega}{\omega_0} - \frac{\omega_0}{\omega}\right)^2 = -k\left(\frac{f}{f_0} - \frac{f_0}{f}\right)^2 = -k\left(\frac{\lambda_0}{\lambda} - \frac{\lambda}{\lambda_0}\right)^2 \quad (3)$$

BAND STOP

$$s = \frac{-k}{\left(\frac{\omega}{\omega_0} - \frac{\omega_0}{\omega}\right)^2} = \frac{-k}{\left(\frac{f}{f_0} - \frac{f_0}{f}\right)^2} = \frac{-k}{\left(\frac{\lambda_0}{\lambda} - \frac{\lambda}{\lambda^0}\right)^2} \quad (4)$$

It is readily seen from this that the effect of using values of k greater than 1 is to decrease the width of band.

An Example.

For example, suppose that we wish to design a band pass filter to pass wavelengths of 2 700 to 3 300 metres, *i.e.*, frequencies of (say) 90 to 110kC, f_0 will obviously be 100kC, and we want s to be somewhat above 4 for $f/f_0 = .9$.

Straightforward calculation shows that for

$$\frac{f}{f_0} = .9, \left(\frac{f}{f_0} - \frac{f_0}{f}\right)^2 = .045.$$

Therefore, if s is to be, say, 4.5 at this point, k must be 100, *i.e.*, $L_1 = 100\,L_2$, and $C_1 = C_2/100$.

From this point the design can be carried on exactly as in the original article, which, it will be remembered, led to finding $Z_2 Z_e$, which is either a constant or is found as a

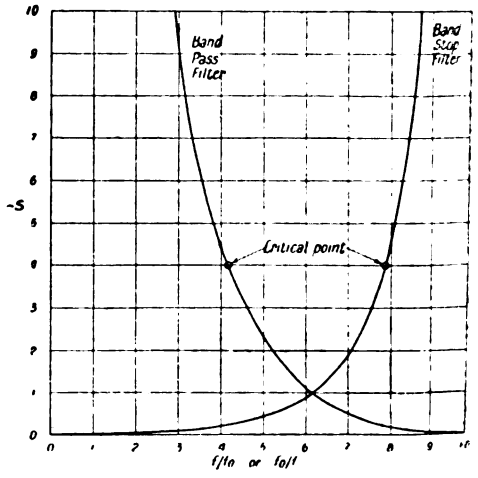

Fig. 4.

function of frequency. Z_e being the known load, Z_2 is thus found for some frequencies, and as we know its form (it is a coil either in series or in parallel with a condenser), we can find quite easily the separate values of L_2 and C_2, whence, knowing the value of k, we can find L_1 and C_1.

Naturally, the design of band filters of this type is not such a perfectly simple matter as that of simple high pass and low pass filters; but it will still be found not to present any serious difficulties if tackled on these lines.

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5JX. An Amateur Station.

By Marcus G. Scroggie, B.Sc. **[R625**

General Description.

UNTIL recently the call 5JX has been known to many radio experimenters as one of the few assigned to Scottish stations, having worked from Edinburgh for a period of two years; but it has now been removed to the neighbourhood of London. The fact that transmissions from this station are fewer and feebler does not indicate that experimental work has ceased, and it is owing to the experiments arising out of the change of supply current from D.C. to A.C. that it is thought that an account of some of the experience gained in connection with the working of the station would be of interest, particularly to those who are new to transmitting.

The principal work in view when transmitting was contemplated was the investigation of fading and similar effects experienced with short waves. Owing however to the necessity for economy in expenditure, a large part of the time was taken up in working out schemes for the provision of a cheap H.T. supply. A machine which was developed for this purpose has already been fully described in this journal[1] and elsewhere.

The First Apparatus.

When the licence was received in October, 1922, the 440-metre wave was the one commonly used, and a trial set was rigged up from Mark III. tuning coils, an R valve, and the 230-volt supply directly applied. This involved practically no expense, as all the components were ready to hand in connection with receiving. The power was limited to about 2 watts, but otherwise the arrangement was very satisfactory, as there was no noise nor moving machinery to start up, and no elaborate smoothing system was required to produce a wave free from ripple. It might be mentioned that this convenient form of H.T., with or without the addition of a supplementary dry battery, was frequently used for low power work and for this purpose was ideal. The input was later increased to 7 watts at 230 volts by the use of a Mullard 0/20 valve, which, by the way, is the only transmitting valve which has been used.

Early Duplex Work.

Some very interesting experiments in duplex telephony were carried out, using this form of H.T., preferred on account of the absence of interference with the receiver. In the first arrangement the wave used for transmitting was 200 metres, while the replying station (2TF) used 440 metres. This wide spacing of wave-length was used partly because of the waves allotted and partly because duplex could be carried on without special apparatus or tuning systems, except that separate aerials were used for sending and receiving. The results obtained in this way over a short distance were perfectly satisfactory, and there is no reason why it should not work over a much greater distance, as no excessive "side tone" was produced, even when amplification was used for working a loud-speaker.

This system was improved by abolishing the extra aerial, the receiver being connected to the same aerial as the transmitter through a rejector circuit *LC* tuned to the latter, as shown in Fig. 1. This method enabled the stations to work on more nearly equal wave-lengths; 130 and 150 gave more than ample spacing. The circuit diagram shows the system of modulation which (after trial of dozens of methods) proved the best. The results were very nearly,

[1] E.W. & W.E., February, 1924.

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if not quite, as good as with choke control, and the apparatus is much simpler, as only an R valve is required as modulator, and no extra H.T. supply or speech amplifier.

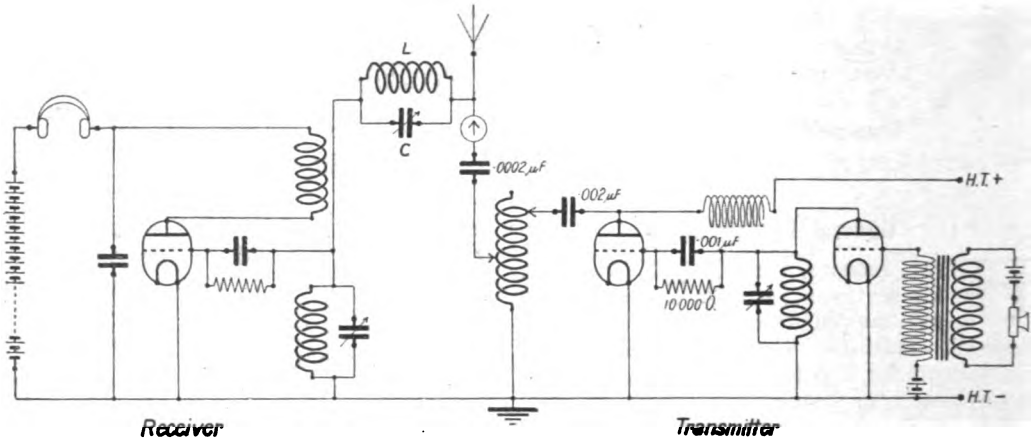

Fig. 1.

This system of duplex working is less complicated than those generally described, and for the powers ordinarily used by amateurs is very effective.

Experiments with A.C. Supply.

It has been mentioned that the 230-volt supply was used pending the development of a more powerful arrangement, and experiments were commenced using A.C. A small fan motor was adapted by fitting two slip rings on the shaft, and connecting these to an opposite pair of commutator segments. This improvised rotary converter delivered slightly less than the theoretical 163 volts A.C., which was stepped up by a very well designed and crudely constructed transformer, consisting of 1½ lbs. of 36 wire, ¾ lb. of 24, about 3 lbs. of banding iron, and a roll of insulation tape—nothing else. This worked quite well, supplying 800 volts, which agreed almost exactly with that designed for. At the time (1922) the use of chemical rectifiers for high tension supply for transmitting was unknown to the writer, so these were tried. Many attempts were made to produce a satisfactory rectifier, but the chemical tubes were finally given up in disgust as ineffective and messy. Others appear to have obtained quite good results with this type of rectifier, owing no doubt to the greater amount of experience which has been gained with them.

In looking about for some other source of power, two old 1/6th h.p. motors which had broken down at an engraver's works were picked up, the field coils of one and the armature of the other rewound, the two machines connected up by a mechanical coupling and used as a booster; one machine being driven off the mains and the output of the other connected in series with the mains, giving a total of 400 volts. (Fig. 2.)

Both field circuits were run off the mains. When this was brought into use the wavelength employed was brought from 440 to 200, a primitive counterpoise was put up, and two R valves used in parallel, so that an input of 100 watts and an aerial current of 0.4 amp was obtained. That evening a test call was made, and great excitement was caused when a reply was immediately picked up from 2DF, 340 miles away, which was no small distance at the beginning of 1923, so great has been the advance in amateur communication since then.

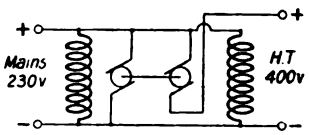

Fig. 2.
The H.T. supply from booster.

A Further Improvement.

Just at this time it occurred to the writer that if a number of condensers were connected in series and each charged to 230 volts by the house supply, a high voltage would be obtained. Various types of commutators for effecting this charging as frequently as possible were thought of, and

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as a radial one with rotating brushes seemed to be the simplest, a number of switch contact studs were mounted on a small ebonite panel, these being connected to fixed condensers of about 3μF, four in series. It was seen that the design would require to prevent short-circuiting of the brushes or condensers at any point, and yet the former could not be allowed to rub over the ebonite between metallic contact, or metal dust would soon cause leakage and flash-over. The studs were, therefore, mounted well clear of the panel by condenser spacing washers, and dead studs were placed between the live ones. Two phosphor bronze brushes connected to the 230-volt input were rotated by means of the old fan motor previously mentioned, and great was the joy at seeing a voltmeter at the output end jump up to 800. After improvements, such as larger condensers, a commutator cut out of sheet copper, and laminated brushes, the device took the form illustrated in *The Wireless World and Radio Review*, 15th August, 1923. This machine gave 18 months' constant service without alteration.

Some Results.

A plug switch was used for connecting the condensers so as to obtain various voltages and it was commonly used at 400-600 volts. Shortly after first working, 8BF, 600 miles distant, reported good reception. This showed that the middle of summer was not against getting good results on low power.

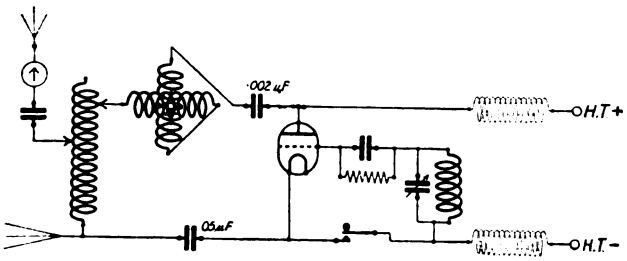

Fig. 3.

A regular schedule of fading tests was arranged, which enabled curves of signal strength to be obtained simultaneously at a number of stations, thus showing whether fading took place in a similar manner at different positions. Results indicated that even at stations whose distance apart was only about 1 per cent. of the distance from the transmitter, no similarity in fading could be traced.

Unfortunately much further information could not be obtained owing to the difficulty in securing a sufficient number of simul-

Fig. 4.

taneous reports. The system used, however, was shown to be quite sound, as any moment of time, within about a second, was definitely traceable on all the records obtained.

The winter 1923-24 saw the commencement of transatlantic communication on the part of British amateurs. 5JX was out of action during most of the time, but in the spring several attempts were made using the newly popular 115-metre wave, and we finally succeeded in "getting over." The circuit used is shown in Fig. 3, which will be recognised as the so-called 1DH circuit. Attention is drawn to the method of keying, which has the advantages of absence of chirp, absence of sparking even if used on higher powered sets, and the total cut off of anode current except when actually radiating, thus less heating of the valve. The aerial was not very satisfactory, being only about 30 feet high and consisting of a single stranded wire, with a 3-wire counterpoise which was not properly under the aerial. The aerial current was 0.7 amp with 25 watts input.

The layout of the apparatus is shown in Fig. 4, in which the A.T.I., built of 10 turns of copper strip, is to be seen in the top right-hand corner, the rest of the transmitter below it, and the receiver on the left. The

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latter uses what is essentially the same circuit as was in use five years ago—a simple single valve reaction circuit with an optional L.F. valve. A heterodyne wavemeter is also incorporated. This receiver gets anywhere and so no elaborate arrangement has been required, and a large band of waves can be searched with one knob.

A Long-distance Transmitter.

A slightly improved transmitting circuit which gave wonderful results in the way of consistent long-distance working is shown

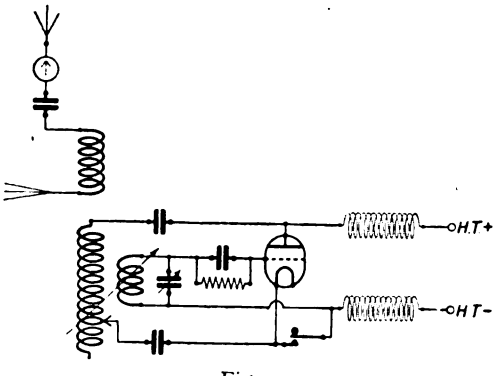

Fig. 5.

in Fig. 5. This is the one now used. The A.T.I. consists of two turns of copper strip 13 inches in diameter, and tightly coupled to 10 turns (variable) on the same skeleton former. The reaction coil has 4 turns, 8 inches diameter, and as this is insufficient in itself a .000 5μF condenser is used for tuning it. The idea of this is to provide a relatively large tuning capacity so that small variations in capacity of the aerial, etc., will have the minimum effect.

Reference has been made in this journal to a Canadian member of the A.R.R.L. who spent the summer of 1924 in the middle of the Atlantic. The writer first heard of this on returning from holiday, and knocked together the transmitter just described in two days for the express purpose of working him. This was done at the very first attempt, and in a period of four successive days, the Atlantic, the English Channel, France, Belgium, Luxembourg, Denmark, and Finland were worked, many of them several times, all were raised by the first call, all reported R7 or R8, and very favourable comments were made on steadiness of wave, Finland going so far as to say 5JX was the best of over 20 British stations worked to that date. This good working in midsummer, on low power from the original voltage raiser, is largely attributed to the circuit and method of keying, both of which are recommended to DX men.

The Move to London.

On moving to London the supply was found to be 200 volts A.C., so the D.C. voltage raiser was useless. In the article in E.W. & W.E. referred to, an A.C. voltage raiser is described similar to the D.C. type but necessitating a synchronous motor. It was seen, however, that a much simpler arrangement could be used if the number of condensers in series was reduced to two, as then a simple contact arm vibrating between two fixed contacts would, if in correct phase with the supply voltage, charge the two condensers alternately. The cheapest way of bringing this about was by means of a Weston moving coil relay, which was connected up as in Fig. 6. As the peak voltage of a 200-volt A.C. supply is 280, theoretically 560 volts could be obtained by this method, but in practice this is reduced to about 450 volts, partly because the contact extends beyond the moment of maximum alternating voltage, and partly due to the partial discharge of the condensers in between charges.

The cost of this system is extremely small, as no transformer or rectifier is required, and the noise is negligible—an important point when working at night. Some people must needs have their generators in the cellar for this reason. The best

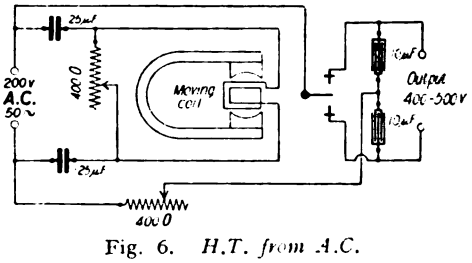

Fig. 6. *H.T. from A.C.*

values of capacity and resistance and the best distance apart of the fixed contacts is found by experiment.

Charging Accumulators.

An almost exactly similar system is used for charging accumulators, and an old

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G.P.O. relay and a D. Mark III. buzzer* have both been used successfully for this purpose. Two Bell transformers, price 12/6, step down the A.C. to a suitable value (Fig. 7). In order to prevent damage being done by any failure of the apparatus when left on charge a reverse-current relay was constructed. The contact to battery and mains is made when a current coil *A* acts in a direction to assist a pressure coil *B*, the latter not being sufficient in itself to hold over the contacts. Any failure or reversal of the charging current therefore completely disconnects the gear. The contacts have to be made by hand when starting up. The same transformers as are used for charging are switched into parallel for L.T. supply to the transmitter.

* E.W. & W.E., September, 1924.

Finally, the writer hopes that this account of the development of a transmitting station

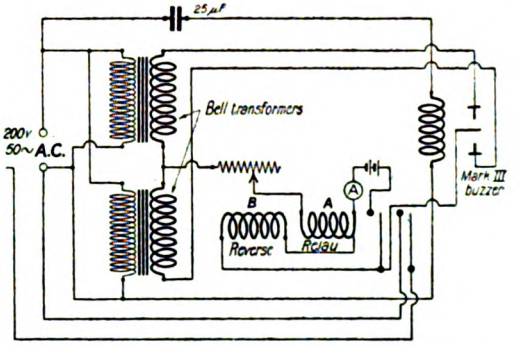


Fig. 7. *L.T. from A.C.*

at the minimum cost may offer suggestions to other experimenters.

The "R.I." Tuner. [R 3822

An interesting component recently submitted to us for test is the new R.I. "Aerial Tuning Reactance Unit." This has been designed to replace plug-in coils which are normally used for aerial and reaction coils. With a .001μF condenser in parallel, the wave-length range covered is stated to be 175-4 000 metres.

The unit consists of a single-layer tapped winding of D.S.C. wire on a Paxolin cylinder 3½ in. in diameter. Inside this, at one end, is pivoted the reaction coil. This is also a single-layer winding on a tube, and operated by a knob which appears on the panel, in conjunction with a well-made bevel gear.

The aerial coil is tapped in eight sections, at 11, 22, 33, 44, 55, 66, 128, and 250 turns respectively. With the object of eliminating "dead end" losses, a special shorting switch is fitted so that the section adjacent to that in use is short circuited.

The construction and finish are all that could be desired, all the mechanical parts being extremely smooth in action. The two knobs project through an ebonite dial, which is suitably engraved, and the sections are lettered A to H.

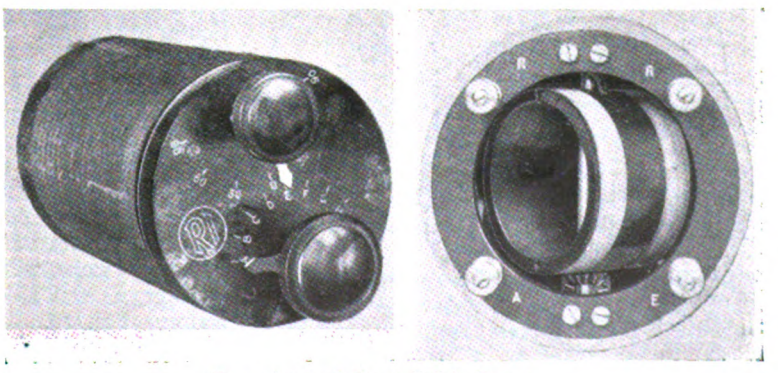
Connections to the two coils are made by four terminals fixed to the back of the component. The aerial winding was covered by a sheet of thin celluloid, which we removed in order to measure the exact size of the wire.

To test the component, we measured the inductance, H.F. resistance, self-capacity and power factor of several sections.

On stud A we found an inductance of 18μH. (The other quantities in this case were not measured.) On stud C the inductance was 119μH (corresponding to a 40-turn plug-in coil), the self-capacity being 8μμF, which is quite good. The H.F. resistance here was about 16 ohms.

We then took a measurement with the shorting arrangements removed. The inductance rose to 153μH, the self-capacity became 18μμF, and the H.F. resistance dropped slightly to 12 ohms. Finally, we made tests on stud H, getting a value of 3 483μH for the inductance, corresponding roughly to a 250 turn plug-in coil. The self-capacity here was only 7μμF and the H.F. resistance 47 ohms. Compared with plug-in coils, these results are quite good.

The power factor, on calculation, proved to be .016, .017 and .014 respectively for the three sets of tests, which is about the same as the average plug-in coils now on the market.



Two views of the "R.I." Tuner.

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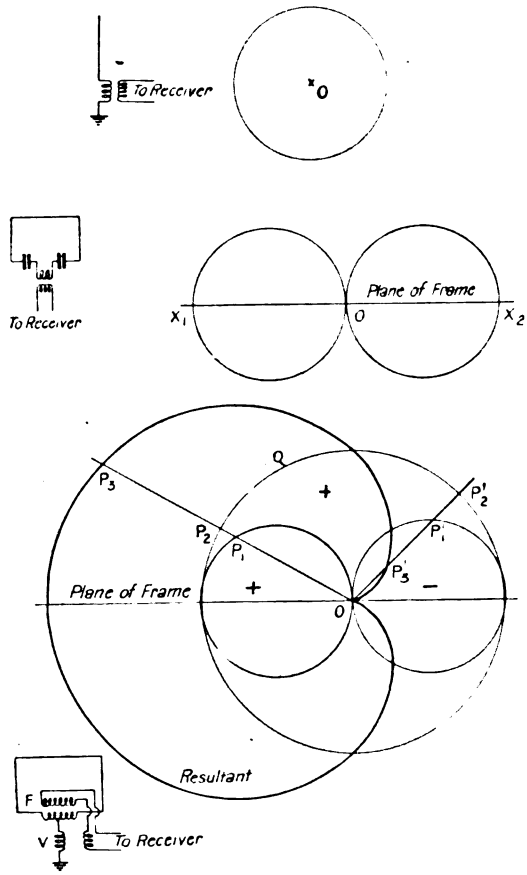
The Polar Curves of Reception for Spaced Aerial Systems.

By E. Green, M.Sc. **[R125·1**

The systems to be described are due to Mr. C. S. Franklin, of Marconi's Wireless Telegraph Company, Ltd.

THE first experiments with polar curves were begun at Broomfield in 1913, but were discontinued on account of the war. The experiments were continued at Letterfrack and Towyn during 1919-20. The completed systems have been in continuous use there since that time until these stations were closed down, and have proved their marked superiority over open aerials or single frame aerials.



Figs. 1*a*, *b* and *c*.

They provide a receiving system with marked directional properties, resulting in the reduction of atmospheric disturbances, as compared with the signal, and the elimination of possible jamming stations.

It is not proposed to give here a detailed description of the circuits used, or of their actual performance, but only an outline, so as to bring out clearly the fundamental principles, and we shall confine the study to signals on the horizontal plane.

2. The best way of showing the directional effect of a receiving system is by polar curves. These are constructed as follows: a point O is taken and lines drawn from it in all directions, of lengths proportional to the

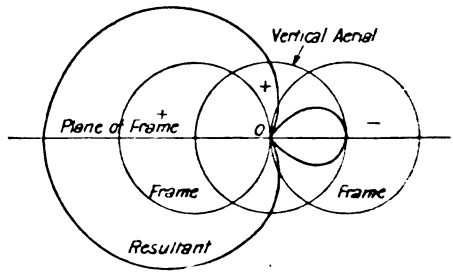


Fig. 1*d*.

intensity of signal received from that particular direction. Hence:—

(i.) The polar curve for reception in the horizontal plane for a vertical aerial is a circle with pole O as centre (see Fig. 1*a*); *i.e.* signals are received equally well from all directions.

(ii.) The polar curve in the horizontal plane of a single closed vertical frame consists of a figure of eight, made up of a pair of equal circles with pole at O, the point of contact, $X_1 O X_2$, being in the plane of the frame. Fig. 1*b*.

Also it is to be noted that a pair of vertical frames fixed at right angles properly coupled

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to a radiogoniometer are equivalent to a single rotatable frame.

(iii.) By adding a vertical aerial E.M.F. to the E.M.F. derived from the frame a heart-shaped polar diagram is obtained, provided this vertical component is equal in magnitude to the maximum E.M.F. from the frame, and is in (or opposite in) phase to the frame E.M.F.[1] These conditions can be fulfilled

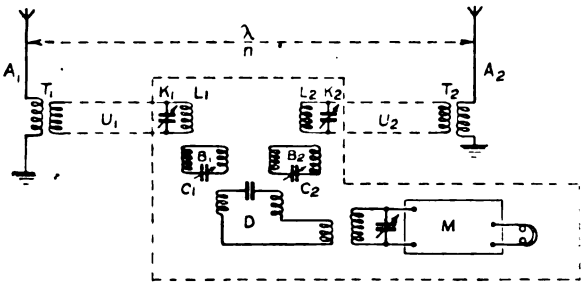

Fig. 2.

with suitable circuits. A skeleton diagram of the connections is shown in Fig. 1c. The frame component of E.M.F. is derived from the transformer F, and the vertical component from the transformer V, which utilises the frame as an open vertical aerial. Fig. 1c also shows how the heart diagram can be constructed graphically. The two circles of the frame diagram are marked positive and negative because the phase of the E.M.F. is reversed when the direction of the signal is reversed. The circle $P_2\ O\ P_2$ shows the signal derived from the vertical aerial taken as positive in phase for all directions.

Then for signals from a direction, such as $P_1 O$, the frame and vertical aerial E.M.F.s are added. ∴ Resultant E.M.F. $= O\ P_1 + O\ P_2 = O\ P_3$, while for signals from direction $P_1\ O$ the resultant E.M.F. is the difference of the two $= O\ P_1' - O\ P_2' = O\ P_3'$.

If this construction is performed for various directions the heart-shaped figure shown in Fig. 1c is obtained.

Fig. 1d gives the polar curve obtained if the vertical component is too weak.

Spaced Aerials.

3. Fig. 2 shows the simplest form of spaced aerial system. $A_1 A_2$ are two similar vertical aerials, their distance apart being some fraction of the wave-length to be received, usually somewhere between 1/6 and 1/10 of a wave-length (call it λ/n).

These aerials are connected through tight-coupled transformers $T_1\ T_2$ and underground cables $U_1\ U_2$ to a central receiving station, indicated by the dotted line.

The aerial systems can be tuned to the wave to be received by means of condensers $K_1 K_2$. $B_1 C_1$ and $B_2 C_2$ are two similar tuned circuits of low decrement. D is a circuit coupled equally to B_1 and B_2, and from D the resultant signal comes through a coupled circuit to the amplifier.

4. Owing to the spacing between the aerials A_1 and A_2 there will be a phase difference in the E.M.F.s induced in them which will depend on the direction from which the signals come.

If $A_1 A_2$ were half a wave-length ($\lambda/2$) apart, the E.M.F.s due to signals from direction $A_1\ A_2$ would be exactly opposite in phase; *i.e.* that in A_2 would be $\pi = 180°$ behind that in A_1. For a spacing between A_1 and A_2 of λ/n the E.M.F. in A_2 would be $360°/n$ behind A_1. For signals coming from the direction $P\ A_1$ (Fig. 2a) making an

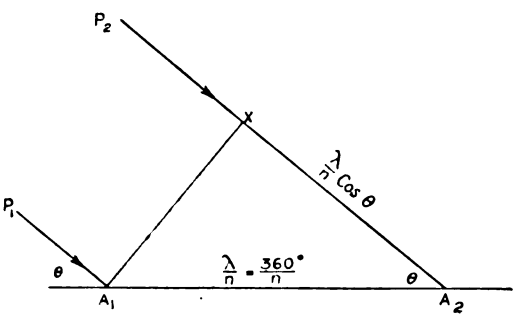

Fig. 2a.

angle θ with $A_1 A_2$, the phase difference will be that due to $XA_2 = \lambda/n \cos\theta$ and will be $360° \cos\theta$.

5. Fig. 3a (next page) shows the phase relations of the E.M.F.s induced in the aerials for eight different directions.

The couplings of B_1 and B_2 are opposed, which is equivalent to reversing one of the E.M.F.s, so that signals from directions perpendicular to $A_1\ A_2$ will cancel out, if there is no phase shift in the circuits.

[1] G. M. Wright and S. B. Smith—"The Heart-Shaped Polar Diagram." *Radio Review*, August, 1921.

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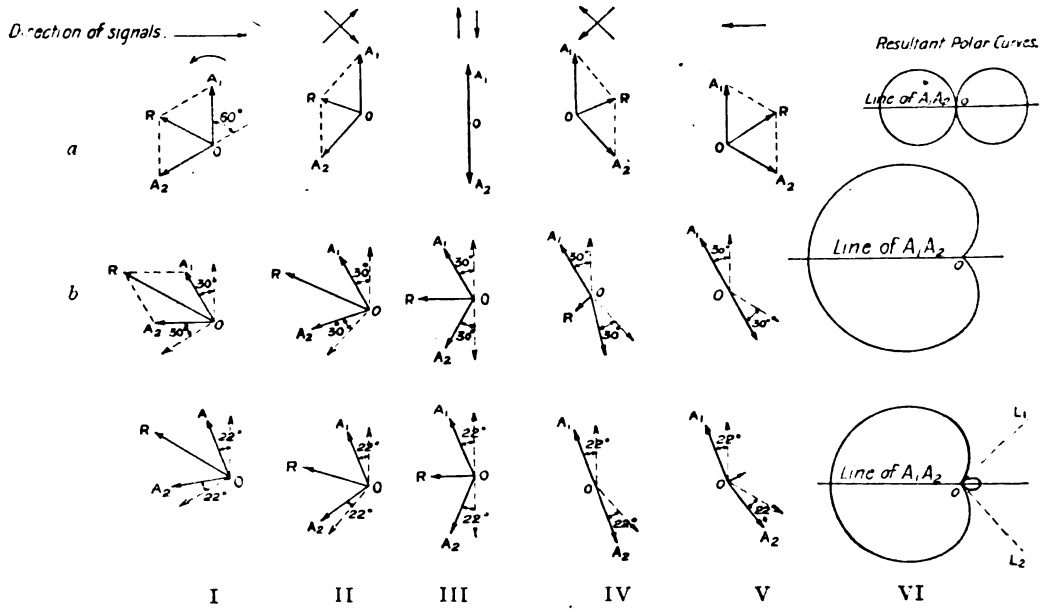
A spacing of 1/6th of a wave-length has been assumed, this makes the maximum phase difference 60°. The positive direction of rotation of the vectors is counter-clockwise. The straight arrows at the top show the direction of the signal. The resultant signal obtained by combining the two E.M.F.s is given by $O\ R$. The resultant E.M.F. is a maximum for the directions $A_1 A_2$ and $A_2 A_1$, and zero for the directions perpendicular to $A_1 A_2$. It is therefore a figure eight diagram, the two loops of which are approximately circles (as shown in Fig. 3*a*) and will be assumed to be so.

In fact the system is equivalent to a closed frame with sides at A_1 and A_2.

receiving circuits themselves, in a way to be described, and is therefore independent of the direction from which the signal comes. Hence the phase relations of the E.M.F.s are now as drawn in Fig. 3*b*. The resultant polar curve is the heart-shaped figure on the right. Its shape is practically identical with that of Fig. 1*c*, and it can be constructed graphically in the same way.

7. The required phase shifts of the E.M.F.s from A_1 and A_2 are obtained by mistuning the low decrement circuits B_1 and B_2 by a slight alteration of the capacities C_1 and C_2 (Fig. 2).

Fig. 4 shows the variations in magnitude



Figs. 3*a*, *b*, and *c*.

6. A more useful polar diagram however would be one which gave a maximum strength of signals for the direction $A_1\ A_2$, and zero strength for signals from the opposite direction $A_2\ A_1$.

From Fig. 3*a* (*V*) we see that to achieve this we must alter the phase relation of the two E.M.F.s as shown in Fig. 3*b* (*V*). That is, we must advance the phase of $O\ A_1$ 30° and lag $O\ A_2$ 30°. The dotted lines indicate the original positions of $O\ A_1$ and $O\ A_2$ whilst the full lines give the new positions.

This phase shift is performed in the

and phase of the current in a circuit as the capacity is varied. The decrement of the circuit is taken as .008.

It will be noticed that to obtain the 30° advance on $O\ A_1$ capacity C_1 must be decreased by .3 per cent. and to get the 30° lag on $O\ A_2$, C_2 must be increased by .3 per cent.

This mistuning reduces the currents to .866 of their resonance values, but this is inevitable.

The phase shift by mistuning can only be performed for wave-lengths which are very close to the wave-length to be received. For

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wave-lengths well outside this range, the small alterations of C_1 or C_2 hardly affects the phase. But these wave-lengths are not important as they can be tuned out in the

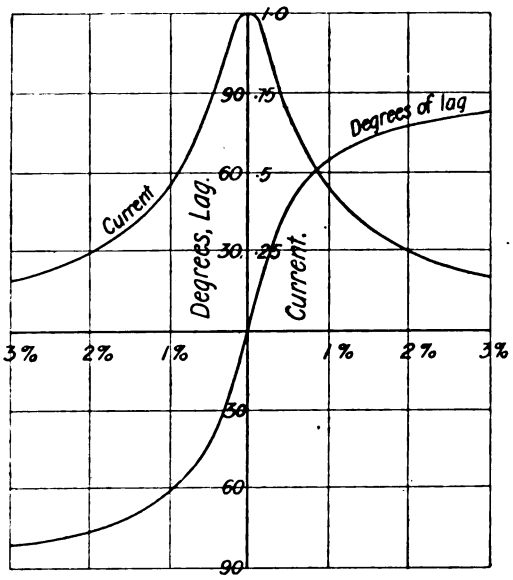

Fig. 4.

ordinary way, by low damped intermediate circuits.

We shall therefore take it that the polar curve is approximately a heart shape for wave-lengths likely to affect the receiver.

8. If the misphasing is given an intermediate value, say $O\ A_1$ advanced 20° and $O\ A_2$ lagged 20°, we get the vector diagram shown in Fig. 3*c* and the resultant polar curve is also shown. It has minima in directions $O\ L_1$ and $O\ L_2$, and such an arrangement can be used to cut out jamming from these directions.

It is similar to Fig. 1*d* and can be constructed in the same way.

The most important case, however, is that giving the heart-shaped curve dealt with above.

9. As the spacing between the aerials is increased the resultant signal strength on the maximum will increase as shown in Fig. 5, where allowance is made for the weakening due to the mistuning of B_1 and B_2. The E.M.F. given by one aerial alone is taken as the unit of signal strength.

The increase of strength with spacing is rapid up to about 1/10th of a wave-length, and the maximum is obtained with spacing between 1/5 and 1/6 of a wave-length.

Although these diagrams only apply strictly to undamped wave signals, they are approximately true for spark signals, and to a considerable extent for atmospheric disturbances.

In practice it is found that the combination of two spaced aerials is more free from atmospheric disturbances than a single aerial. At some times the effect is much more marked than at others, *i.e.*, if a large proportion of atmospherics are coming from the same direction as the signals to be received, *i.e.*, $A_1\ A_2$, not much reduction is to be expected, while if they are coming from the opposite direction, the reduction will be marked.

10. So far we have dealt with the results that can be obtained from the combination of two spaced plain aerials, as this is the most simple case. But in actual practice the plain aerials are replaced by pairs of D.F. frames connected through underground cables to radiogoniometers in the receiving hut. (See Figs. 6*a* and 6*b*, next page.) In 6*a* each pair of D.F. frames will give a figure eight diagram, whilst in 6*b* extra connections are made so that a vertical component can be obtained to produce a heart diagram from each individual set of frames. The frames A_1 and A_1' are a pair of D.F. frames and are shown separately on the figure for convenience of drawing the connections, similar remarks also apply to A_2 and A_2'.

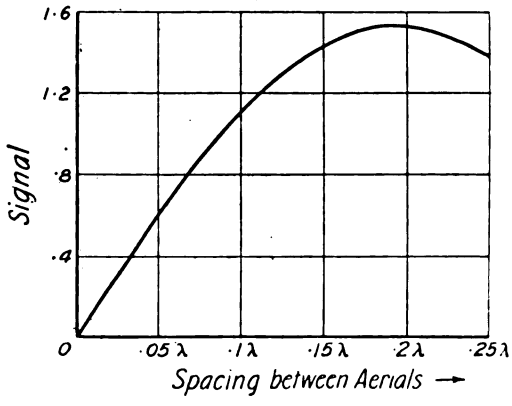

Fig. 5.

In 6*a* we have two twin cables from each pair of frames. $L_1\ L_1'\ L_2\ L_2'$ constitute the fixed coils of the radiogoniometers, S_1 and S_2 the rotating search coils.

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In 6*b* we have extra circuits made up of T_1 U_1 V_1 and T_2 U_2 V_2 to provide the vertical components for the heart diagram.

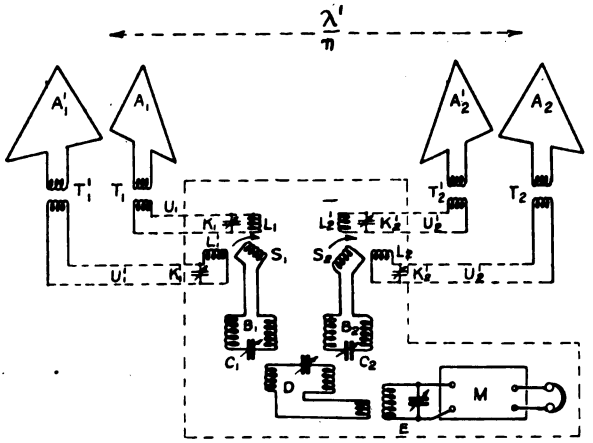

Fig. 6*a*.

For the rest the circuits are identical with those of Fig. 2 for open aerials and have been similarly lettered. B_1 C_1 and B_2 C_2 are the misphasing circuits as before.

11. We have now to show how to find the resultant polar curves, obtained with systems such as 6*a* or 6*b*. We may regard each pair of frames, as A_1 A_1' with its associated radiogoniometer, as equivalent to a single rotatable frame. Take the case of 6*a*: each pair of frames gives a figure eight diagram which rotates as the search coil is rotated. Suppose the search coils are set so that the equivalent frames lie along A_1 A_2 and therefore the figure eight curves for each set of frames are as shown in Fig. 7*a*. Also let the misphasing circuits B_1 B_2 be set so as to give a minimum from the direction A_2 A_1: *i.e.*, if we had simple open aerials at A_1 and A_2 the combination would give us the heart diagram of Fig. 3*b*, shown dotted in 7*b*. The polar diagrams of Fig. 3 we shall refer to as the open aerial combination diagrams or spacing and phasing diagrams. Then it is obvious that with the search coils set as above no signals are received on either set of frames from directions at right angles to $A_1 A_2$. Therefore the heart diagram due to the misphasing must be pinched in to zero in these directions.

The resultant polar curve is shown in Fig. 7*b*, which is derived as follows: If we had open vertical aerials at A_1 and A_2 instead of frames, giving E.M.F.s, equal to $O_1 M_1 = O_2 M_2$ (Fig. 7*a*), the resultant is $O\ M$ (Fig. 7*b*). For any other direction, such as $P_1\ O_1$, with open aerials, the individual E.M.F.s would still be equal to $O_1 M_1 = O_2 M_2$ but the resultant would be $O\ P$ on the heart diagram. But with the frames at A_1 and A_2 the individual E.M.F.s for the direction $P_1\ O_1$ are reduced to the value $P_1\ O_1$. Therefore the resultant E.M.F. for the combination will be reduced in the same ratio, and is equal to $O\ P \times \frac{O_1\ P_1}{O_1\ M_1}$ *i.e.*, it is proportional to $O\ P \times O_1\ P_1 = O\ Q$ say, since $O_1\ M_1 = O_2\ M_2 =$ constant.

12. Hence the following construction will give us the resultant diagram of the combination of spaced frames: The figure eight diagram of the individual frames is superimposed on the spacing and phasing diagram for the open aerial combination in its proper relative position as in Fig. 7*c*.

Then for any direction, such as $X\ O$, the

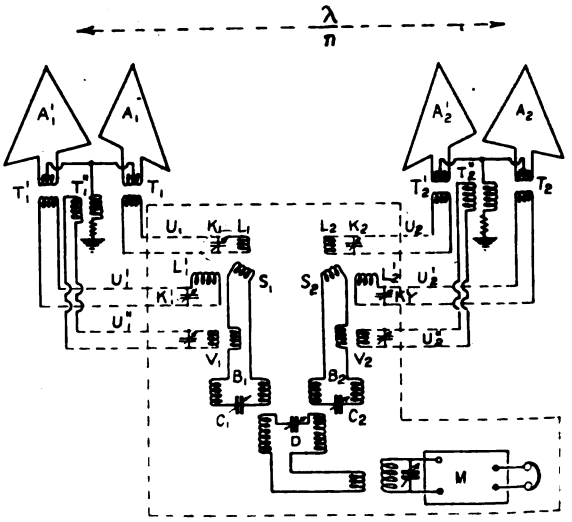

Fig. 6*b*.

resultant vector for the frame combination will be $= O\ P \times O\ P_1 = O\ Q$.

This process may be termed multiplying one polar diagram by the other.

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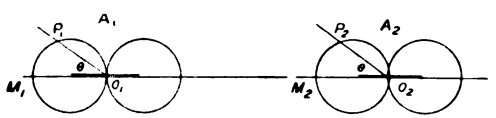
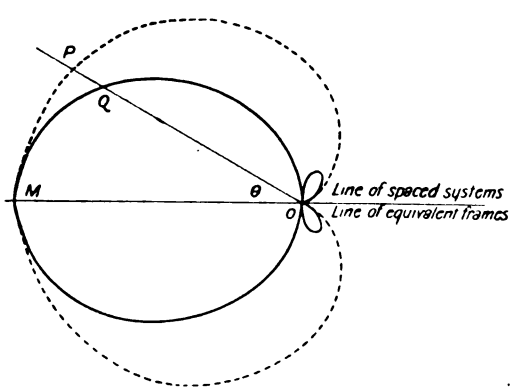
The scale on which the two diagrams are drawn will not affect the shape of the resultant diagram which is also shown in Fig. 7*d*.

The table below gives the relative values of the vectors in the figure eight and heart diagrams at intervals of ten degrees, starting from the maximum values. The third column gives their product, which is the value of the vector on the resultant diagram for the same direction. Fig. 7*c* is constructed from these figures. This table will be found of use in constructing the later diagrams.

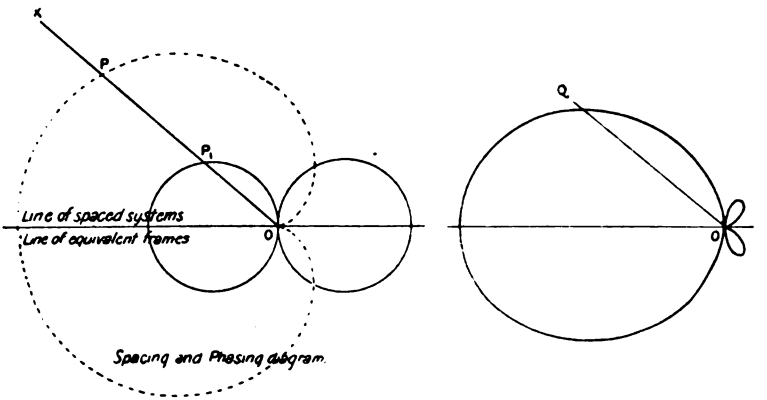
13. As might be expected, the resultant diagram is much better than that obtained with open vertical aerials, and will give correspondingly better results in practice as regard freedom from jamming and atmospherics.





Figs. 7*a* and *b*.

14. By the above method we can easily determine what happens when we vary one of the two main factors, *e.g.* :—



Figs. 7*c* and *d*.

(1) Rotation of the search coils of the radiogoniometers. In practice these will always be moved through equal angles so that the equivalent frames remain parallel.

(2) Alteration of the amount of misphasing in B_1 & B_2.

Take as an example of (1); the search coils of the radiogonometers are rotated through an angle of 30° in the counter clockwise direction, so that the equivalent frames and the individual polar curves are

Angle θ degree.	Vector of Fig. 8 diagram $=\cos\theta$.	Vector of Heart diagram $=(1+\cos\theta)$.	Vector for Combination $=\cos\theta\,(1+\cos\theta)$.
0	1.0	2.0	2.0
10	.985	1.985	1.96
20	.94	1.94	1.82
30	.866	1.866	1.60
40	.766	1.766	1.35
50	.643	1.643	1.06
60	.500	1.500	.75
70	.342	1.342	.46
80	.174	1.174	.205
90	0	1.00	0
100	—.174	.826	.143
110	—.342	.658	.244
120	—.500	.500	.25
130	—.643	.357	.238
140	—.766	.234	.179
150	—.866	.134	.116
160	—.94	.06	.056
170	—.985	.015	.015
180	—.100	0	0

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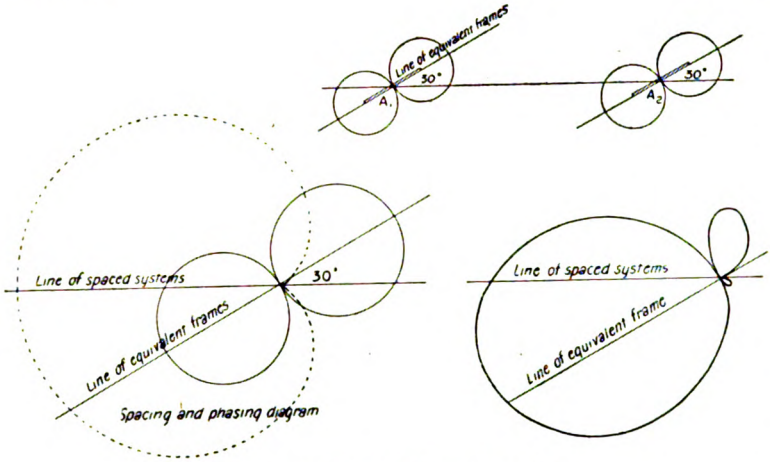

Fig. 8*a* (above), 8*b* (left) and 8*c* (right).

as shown in Fig. 8*a*. The misphasing, and therefore the heart combination diagram, is unaltered. Superposition gives Fig. 8*b* with the resultant polar curve shown in Fig. 8*c*. One of the back loops is enlarged and the other is reduced in size, and the strength in direction $A_1 A_2$ is reduced. The figures for this calculation are given below. Those for the figure eight diagram have been moved up 30° compared with those in the previous table, whilst the figures for the heart are unchanged. As the figure is unsymmetrical it is is necessary to make out the table for the whole 360°.

15. Next with the search coils in their original position so that the equivalent frames are along $A_1 A_2$, let the misphasing be reduced. The open aerial combination diagram is now that of Fig. 3*c* (*VI*) and superposition of the diagrams as in 9*a* yields the resultant of 9*b*. Figs. 9*c* and 9*d* give the superposed and the resultant diagrams when the misphasing is less than in 9*a* and 9*b*.

Many such varying combinations can be worked out.

16. The same method can be applied to any combination of two or more similar spaced aerial systems. Consider the system outlined in Fig. 6*b*, where each pair of D.F. frames is connected so as to give a heart diagram (by obtaining a vertical component from the frames through the transformers T_1 and T_2). For example, let the equivalent frames lie along $A_1 A_2$ so that the individual heart curves have $A_1 A_2$ as axis, Fig. 10*a*. If B_1 and B_2 are in tune, *i.e.*, no misphasing, the open aerial combination diagram is a figure eight as in 10*b*. Superposition gives the resultant curve shown in 10*c*. It is identical with that of 7*b*, although its derivation is so different.

17. If now B_1 and B_2 are misphased so as to give a minimum behind A_2 the open aerial combination diagram is a heart, so

Angle θ degree.	Vector of Fig. 8 diagram. $=\cos(0+30°)$	Vector of Heart diagram. $=(1+\cos\theta)$	Vector of resultant diagram. $=(\cos(\theta+30°))(1+\cos\theta)$
0	.866	2.0	1.73
10	.766	1.985	1.52
20	.643	1.94	1.25
30	.500	1.866	.933
40	.342	1.766	.605
50	.174	1.643	.286
60	0	1.500	0
70	—.174	1.342	.234
80	—.342	1.174	.402
90	—.500	1.0	.50
100	—.643	.826	.53
110	—.766	.656	.50
120	—.866	.500	.433
130	—.94	.357	.335
140	—.985	.234	.23
150	—1.00	.134	.134
160	—.985	.06	.06
170	—.94	.015	.014
180	—.866	0	0
190	—.766	.015	.011
200	—.643	.06	.038
210	—.5	.134	.067
220	—.342	.234	.08
230	—.174	.357	.062
240	0	.5	0
250	+.174	.656	.114
260	.342	.826	.282
270	.5	1.0	.5
280	.643	1.174	.755
290	.766	1.342	1.03
300	.866	1.5	1.3
310	.94	1.643	1.54
320	.985	1.766	1.74
330	1.0	1.866	1.866
340	.985	1.94	1.91
350	.94	1.985	1.87
360	.866	2.0	1.73

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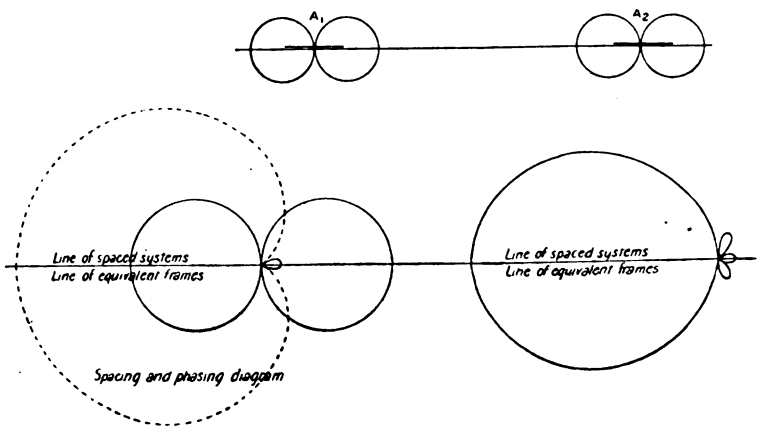
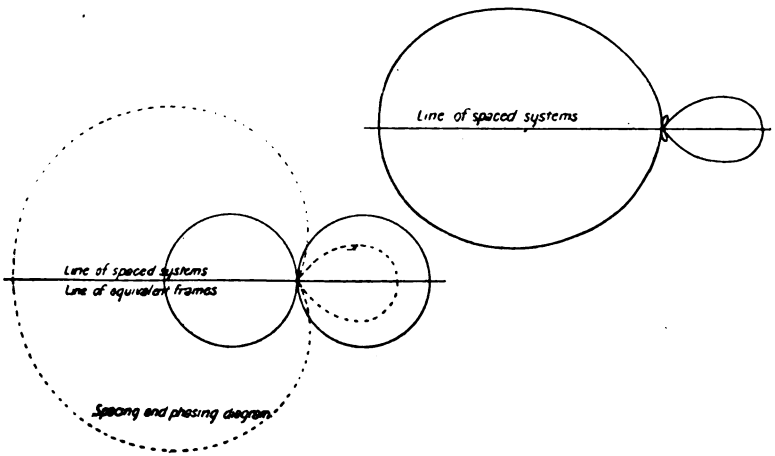
that the resultant diagram is also heart shaped, but the minimum behind is wider. This is shown in Fig. 11 (next page).

The signal strength on the maximum will be almost twice that of Fig. 10*c*.

Now keeping this degree of misphasing we might swing the search coils round 30° to minimise atmospheric disturbances from a particular quarter. The individual hearts are now as 12*a* (next page), the superimposed diagrams as 12*b* and the resultant diagram as 12*c*.



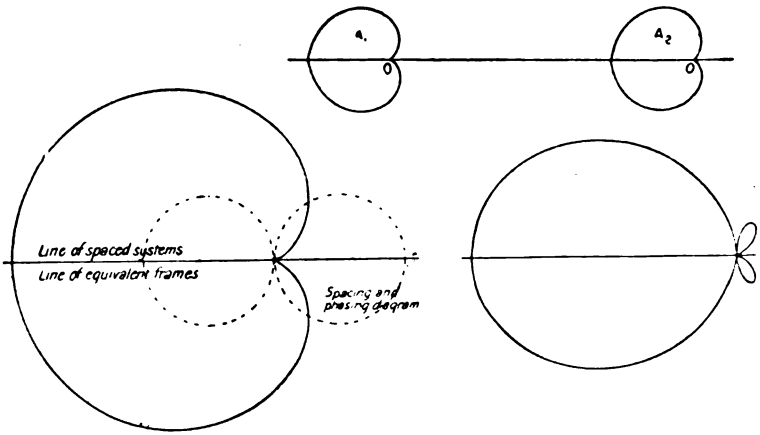
Figs. 9*a* (left) and 9*b* (right).



Figs. 9*c* (left) and 9*d* (right).

18. In practice the system outlined in Fig. 6*b*, (*i.e.*, a vertical aerial component combined with the frame E.M.F.s so that each pair of frames gives a heart diagram) gives better results than one using plain D.F. frames. The single minimum on the heart diagram is wider than the two minima on the figure eight. Hence, if you are working on one pair of frames, and swing the search coil round, you can usually find a position that gives a very definite minimum of atmospheric disturbance.

When using plain frames this effect is not at all marked. Secondly, the minimum of the heart diagram remains good under night conditions, in which the minima



Figs. 10*a* (above), 10*b* (left) and 10*c* (right).

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on plain frames may disappear entirely.* Thirdly, there is no ambiguity of sense when locating the direction of jamming.

19. The way in which the two E.M.F.s from the two sets of frames will be combined by misphasing will depend on circumstances. In the first place the line of the frames, *i.e.*, A_1 A_2, should point toward the station to be received, and as far as possible all jamming stations should lie behind A_2. The search coils can then be set to give minimum atmospheric disturbance from each frame. Then B_1 and B_2 are mistuned to get maximum signals from the front. Such a case is shown in Fig. 12, where Xs are supposed to be coming from the direction OX. Or, if there is a particularly strong jamming station not quite directly behind, the misphasing is decreased to give a minimum in its direction.

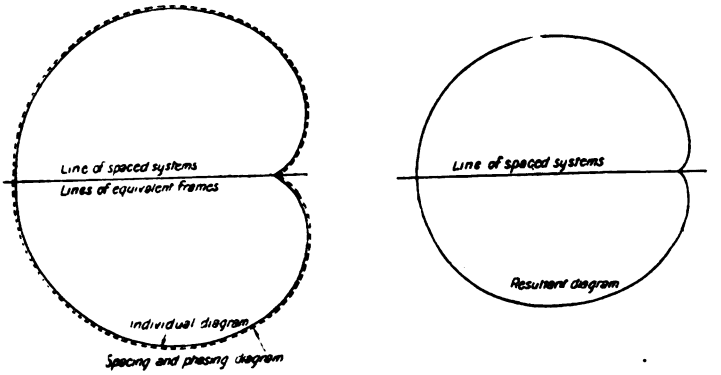


Fig. 11.

Fig. 13*a* and 13*b* show the superposed and resultant diagram for this case.

20. It is not suggested that all these different diagrams should be constructed accurately, to scale. The method is chiefly useful in that it enables us to draw the diagram for the individual sets of frames, and the misphasing diagram, quite roughly in their proper relative positions, and to derive from them by rapid inspection a good general idea of the resultant diagram.

Note that there will be minima on the resultant polar diagram for the same directions that there are minima on either the spacing and phasing diagram, or the individual diagrams.

It is hoped that the method outlined will assist readers to obtain a clear mental picture of what is happening when such circuits are being adjusted.

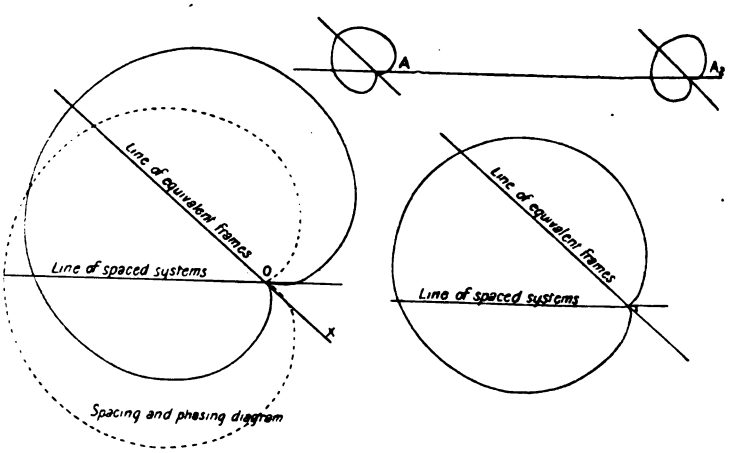
We can now give the general rules for finding polar diagrams (for reception in the horizontal plane) obtained by combining any number of similar and similarly oriented spaced aerial systems. These are as follows:—

(1) Consider each individual system replaced by a vertical aerial, and find the polar diagram obtained by combining the currents from all these vertical aerials, any misphasing being exactly as for the individual system that the vertical aerial replaced. This diagram is called the "*combination*," or "spacing and phasing" diagram.

(2) Find the polar diagram for each individual system.

(3) Superpose the spacing and phasing diagram obtained in (1) on the individual polar diagram obtained in (2) pole on pole and with the proper orientation.

(4) The resultant polar diagram for the complete set of spaced systems is obtained



Figs. 12*a* (above), 12*b* (left) and 12*c* (right).

* See previous reference.

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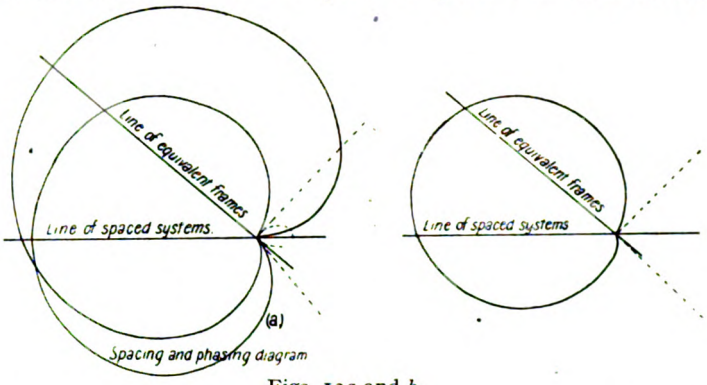
by "multiplying" one of these two diagrams by the other, as described in this article.

If we wish to find the polar figure in three dimensions instead of in two only (the horizontal plane) in (1) we must replace each individual system by a hypothetical receiver that receives equally in all directions instead of by a vertical aerial. The spacing and phasing diagram must then be obtained in three dimensions. Similarly, the polar figure for each individual system must be found for three dimensions. The resultant polar figure is found by superposing one of these on the other in their correct relation and "multiplying" one by the other.

The same method can be applied to find the polar diagram for transmission for any set of similar and similarly oriented spaced aerial systems, though these have not been specifically referred to in this article.



Figs. 13*a* and *b*.

An exclusive picture of the Marconiphone and B.B.C. amplifying apparatus for broadcasting by means of loud-speakers the speeches, etc., made at the recent Wireless Exhibition at the Albert Hall.

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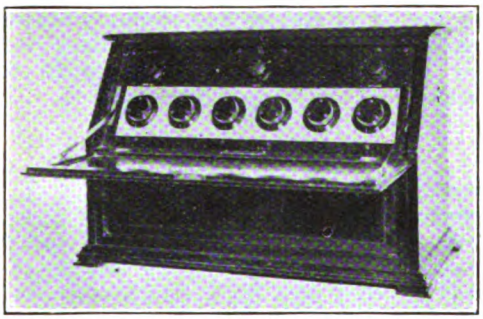
The Albert Hall Exhibition. [R064

A Brief Review of some of the more Interesting Exhibits.

THOUGH the recent successful exhibition staged at the Albert Hall, London, did not bring to light any very startling novelties in apparatus and equipment, it was of interest in that it indicated clearly the improvements in design and construction which have recently taken place, as well as the lines upon which manufacturers are now working.



The "straight eight" receiver developed by the Marconiphone Company. At the moment specification and circuit details are not available.

With one or two exceptions, the trend seems to be towards the detailed improvement of standard design, both from the point of view of mechanical and electrical efficiency, and in the case of broadcast receivers and equipment, from considerations of an æsthetic nature.

In the following pages we propose to give a brief description of such of the exhibits as will be likely to interest our readers, and in doing so we propose first to deal with the receivers which were on view.

Leaving out crystal receivers, of which many ingenious designs were to be seen, we found that valve receivers could be broadly divided into three classes. First, there were sets employing one or two valves. In these, no vast changes were apparent, and in many cases last year's designs had been more or less adhered to. There were several examples of two valve sets, employing a detector valve and one L.F. amplifier with direct aerial reaction, intended for working a small loud-speaker at short ranges from the local station. We cannot help thinking that the quality of the results obtainable from two valves would have been vastly improved by re-designing these sets to have one H.F., crystal detector and one L.F. valve.

The second class of valve sets noticed was what we may call the "luxury" class. In most cases, receivers of this class employed four valves (H.F., detector and 2 L.F.); and were housed in cabinets of excellent construction and finish. Many were available in different "period" designs, and most of them contained all batteries and accessories. In many cases loud-speakers were built in, making the set almost self-contained.

Most of the large firms had sets of this type on view, and almost each set had some distinguishing feature in design or construction. Thus the De Luxe Pedestal set made by the British L. M. Ericsson Manufacturing Co., Ltd., incorporated a simple wave-trap. The Chakphone No. 7, by the Eagle Engineering Co., Ltd., employed a coupled aerial circuit, both primary and secondary being tuned. This set was said to give excellent selectivity.

The Cosmos 5-valve cabinet sets have, of course, been on the market for some time. They make use of special plug-in units for different wave-length ranges, the units containing the aerial and reaction coils and the H.F. transformer. A lever is provided which couples the reaction coil either to the H.F. transformer or to the aerial coil. In a 3-valve amplifier made by this firm, resistance coupling is employed, and the last two valves may be switched in series or in parallel. The first position results in the usual circuit, and maximum amplification is obtainable when receiving weak signals. If strong signals are being received, the valves are switched in parallel, when they are capable of dealing with more power, and risk of distortion due to overloading is eliminated.

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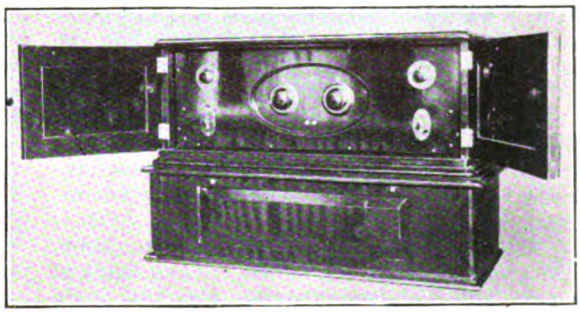
The Radio Communication Co., Ltd., were showing an interesting set in the "Polar Four." This set employs a double tuning system, so that a set can be tuned to a short wave and a long wave station, the change-over from one to the other being easily performed. The most interesting point is, however, that a system of remote control is incorporated. This consists of a control box attached to a long cable which can be plugged into the set by a special plug and socket. In the control box (which is placed in the room where the loud-speaker is situated) is a switch which operates relays in the set, bringing either the long or short wave tuner into action. In addition, the control box contains a rheostat which varies the filament voltage of the detector valve, thus controlling the degree of reaction. Such a device is necessary, otherwise on switching over it might be found that the reaction coupling was too great, resulting in oscillation, which must be avoided at all costs.

So far we have only mentioned sets of the "straight" type with conventional circuits. A rather unusual receiver was the Marconiphone "Straight Eight." As its name implies, it employs eight valves, 5 H.F., detector and 2 L.F., and was designed by Captain Round. It has some novel method of neutralisation of which, up to the present, we have not been able to obtain details. Incidentally, each of these receivers is calibrated in metres.



The handsome de luxe model Burndept supersonic receiver. It costs £84.

The new "Radiosun" receiver designed by Auto-Sundries, Ltd. The loud-speaker is a fixture.

Almost the only other neutralised receiver we noticed was that produced by the British Radio Corporation. This employs 5 valves and has a range of 200-3000 metres, obtained by the use of suitable interchangeable tuners. There seems to be no doubt that this essentially American circuit is finding very little favour over here.

The Ediswan Company were showing a novel 4-valve set, the W.L. 449, employing capacity reaction. The method of manufacture has been so standardised that all instruments are sent out with the tuning condenser calibrated in metres, and individual calibration is not needed.

Perhaps the most novel receiver which we saw was that shown on Messrs. Auto Sundries' stand. This, the "Radiosun," is claimed to operate on an entirely new principle. It employs 5 valves, which are specially manuactured for the firm by a well-known valve manufacturer, and the *total* filament current consumption is only 0.1 ampere. The plate current required is in the neighbourhood of one or two mA at 60 volts. The set is intended for loud-speaker reception at distances up to 25 miles from the local station.

So far we have not been able to obtain full particulars as to the circuit employed, or the special properties of the valves. The set employs a frame aerial concealed at the back, and the only other components visible are a variable condenser and one or two fixed condensers. No L.F. transformers are

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employed, and the makers say that distortion is thereby practically eliminated. Lest it should be thought that this set (which is quite cheap—£18 10s., including loud-speaker and *all* accessories) is another of the "wildcat" schemes of which there are so many prevalent at the present time, we should in fairness say that the inventor of the circuit is a man who has had a good deal of useful experience, and it is quite possible that he has hit upon some revolutionary idea. At this we will leave it, until we have had opportunity of verifying the claims put forward.

We now come, by a process of elimination, to a class of receiver which, during the last year, has made great strides towards popularity—we refer to the supersonic receiver, or, as some call it, the superheterodyne. This time last year the use of this type of receiver was confined almost exclusively to experimenters, and all parts in use were of American origin. To-day, many types of British made supersonic receivers are on sale, and sets of parts are also available. There is no doubt this is largely due to the increasing efficiency of dull-emitter valves. Few members of the general public could manage to run, say, eight bright emitters consuming about 6 amps in all.

At the Exhibition, the number of supersonic receivers was surprising—there were not many of the larger manufacturers who did not show at least one type. In most cases, the parts for building one's own set could be obtained.

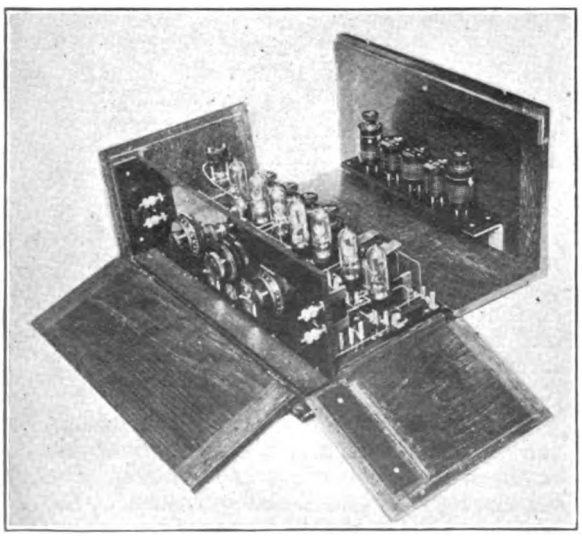
Messrs. Beard & Fitch were showing several supersonic sets and a complete range of their supersonic components. These included the "Superforma" (an intermediate-frequency transformer) and an oscillator coupler. The sets are specially designed for simplicity of control. Apart from the filament resistance and a potentiometer the only controls were the oscillator coupler and the tuning condenser.

Messrs. Bowyer-Lowe were showing no less than six models, all employing their sets of components, which are obtainable separately. The "Popular" model employs 8 valves, and is self-contained except for a frame aerial.

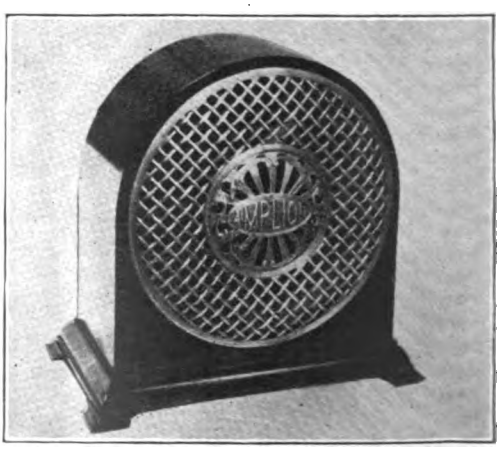
The British Thomson-Houston Co. were showing 6-valve models of both portable (with loud-speaker) and pedestal types.

The Ethodyne, by Messrs. Burndept, is a handsome set, and employs 7 valves: an oscillator, first detector, 2 intermediate frequency, second detector, and 2 L.F. valves. The latter can be switched out if desired. The first detector employs anode rectification, a suitable grid potential being applied for this purpose. The intermediate-frequency amplifiers operate on a wave-length of 6 000 metres. Separate frame aerials are provided for the lower and upper broadcast band.

The General Electric Company were showing two Gecophone supersonic receivers, one 6-valve and one 8-valve. The latter is



An interesting interior view of Messrs. L. McMichael's supersonic set.



One of the "Amplion Radiolux" loud-speakers, which came as a great surprise to most people at the Show.

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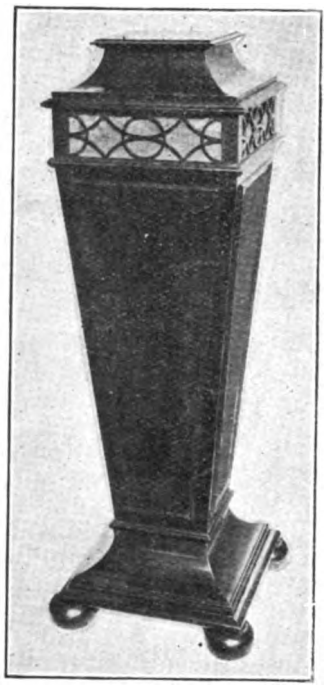
similar to the former. but has two additional L.F. valves, Three intermediate-frequency amplifiers are employed, and work on a wave-length of 5 000 metres. The tuning range is from 175 to 3 000 metres by the use of suitable plug-in units. The only controls are two tuning condensers, and a volume control.

Messrs. L. McMichael have recently produced a set of supersonic components, and on their stand was a 7-valve set employing these. This will shortly be on the market. The first valve is a combined detector and oscillator, which is rendered possible by the centre-tapped "Autodyne" unit. Then follow 3 L.F. amplifiers, the second detector, and 2 (optional) L.F. amplifiers. The first of these is transformer coupled, the second employing resistance-capacity coupling. As an example of compact and neat wiring, this set would be hard to beat.



This pedestal loud-speaker by A. J. Stephens, Ltd., is as much an ornament as an efficient instrument.

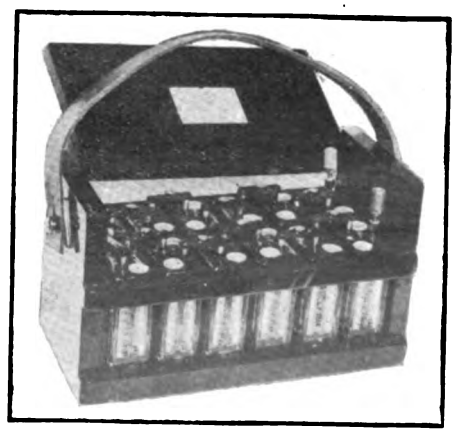
Finally, we should mention the R.I. 6-valve supersonic, which employs the units made by this firm. The oscillator couplers are of a flat circular shape, and the layout and wiring of the set are very well disposed. Two of the new geared R.I. condensers are employed for tuning purposes.

Having now dealt at some length with the various types of sets which were on view, we will consider the accessories to such sets, under which heading we include loud-speakers, batteries (and other devices intended to replace them), and valves.

The tendency in loud-speaker design was, on the whole, towards the production of instruments of the hornless or concealed horn type; though many of the standard horn models were to be seen improvements in which had been confined to details in the design and construction.

The most unexpected innovation in loud-speakers was probably the new Amplion "Radiolux." This, in appearance, resembles the old English bracket clock, the dial of which is replaced by a bulged grille. The electro-magnetic movement is of an improved type, the active dimensions of the diaphragm being increased, and the area of the pole faces of the magnet system being reduced to allow of a high flux density through them. The acoustic system is novel, and is stated to be the result of much research. The sound waves are first led along a gently tapering curved sound conduit and are then reflected at a "bowl" of double hyperbolic section. The orifice of the sound conduit is placed at the focus of the hyperbolic reflector. We hope to have an opportunity of testing this instrument shortly.

Several other novel types of loud-speakers were also to be seen. The British Thomson-Houston type E is of the conical diaphragm type. Over the front of the cone is an open grille, behind which is stretched a panel of silk to diffuse the sound. The A. J. Stevens pedestal instrument consists of a solid mahogany case, in which is a cast straight horn, with a solid reflector which reflects the sound horizontally through the grille at the top. Messrs. S. G. Brown have produced several new models, including a cabinet instrument, and the "H.Q.," a model similar to the well-known "Q," but



The "Hymeg" H.T. accumulator unit made by Ediswan's.

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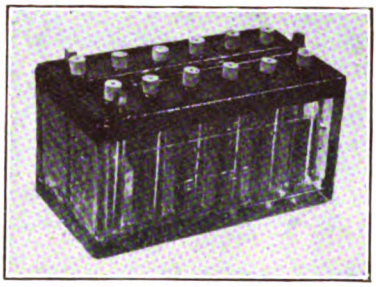
much less costly. The cabinet model is similar in appearance to a "hornless" gramophone, and contains an internal horn. Messrs. C. A. Vandervell and the Radio Communication Company are also showing some novel instruments on these lines.



This Exide "W.H." H.T. battery is a development of the well-known "D.T.G." type cells.

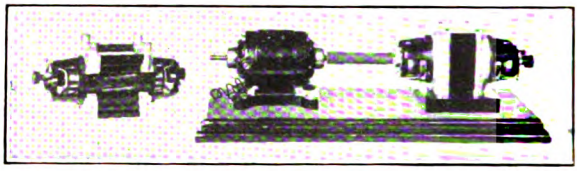
As to batteries and other sources of supply, there were no startling developments. Several firms, notably the Chloride Electrical Co., the Hart Accumulator Co., and Edison Swan Electrical Co., were showing new types of H.T. accumulators. On the stand of the first of these companies, a new glass-cell type W.H. was to be seen, similar in construction to the well-known D.T.G. types. This is stated to hold its charge for six months without damage. On the Hart stand was noticed a new experimental type, the cells of which are placed in a metal container, and are then completely oil-immersed. The oil floats on the acid, and trouble due to spraying and evaporation is eliminated.

Several battery chargers and mains supply units, both for H.T. and L.T. supply, were to be seen, but they appeared to be constructed on conventional lines.

Messrs. S. Smith & Sons, who now deal with the well-known M-L products, were showing a range of M.L. anode converters, small H.T. generators and two-voltage boxes.

The anode converters are, of course, small motor generators which derive their input supply from 6 or 12-volt accumulators. Three types are available, Types N, C and D. They give respectively 120, 300 and 500 output volts, with input voltages of 6, 12 and 12 respectively. When two different H.T. voltages are required, a two-voltage box must be used. This contains an inductively wound resistance with tappings. It also contains a $2\mu F$ condenser and thus serves as an additional smoothing unit. It is also possible to buy the generators with the two-voltage device built in. Two types are available, giving voltages of 120 and 60, and 300 and 60.

Machines can also be supplied with a single winding only, suitable for driving from an external source, and wound for any voltage up to 600 volts. A standard machine is available, giving 30mA at 550 volts at 2 500 r.p.m. This would be suitable for amateur transmitting stations of small power.



The "M.L." anode converter, by S. Smith and Sons (M.A.), Ltd.

We come next to the consideration of the valve exhibits. Messrs. Burndept have now entered the circle of valve manufacturers and are making a complete range of valves for receiving purposes, including power valves. We are glad to note that they have adopted what is, in essence, our own method of classification.

We noticed especially the L550, which is a "super" power valve. The filament current is 0.5 amp at 5.0 volts, and the emission is 60mA. The makers advise the following combinations of H.T., and grid voltages.

H.T.	150 volts,	Grid – 15 volts.
	200 volts,	Grid – 30 volts.
	250 volts,	Grid – 45 volts.

The Cossor Valve Co., were showing two new power valves—the W3 and P3, the former being a "250" and the latter a "425."

The Mullard Radio Valve Company were showing the new P.M.4, which is a "410" power valve, with a specially coated "N" shaped filament, the electrodes being arranged horizontally. A large range of transmitting valves was also to be seen, ranging in power from a "5-watter" to the large silica-cased valves which are features of this firm's products.

The M.O. Valve Company are now making valves for both the General Electric Company (Osram) and the Marconiphone Company (Marconi). Several new types are available. The old D.E.R. is now superseded

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by two forms, the D.E.2 H.F. and L.F., with amplification factors of 12 and 7 respectively. The old D.E.6 has now been slightly modified, the impedance being reduced and the amplification factor slightly raised. This has involved increasing the filament consumption from 0.4 to 0.5 amp, the valve thus becoming a "250."

Two entirely new valves by this Company are the D.E.8 H.F., and L.F. both being of the "612" class. The H.F. model is claimed to be a very efficient detector; the D.E.8 L.F. meeting the demand for a low current consumption power valve.

A comprehensive display of obsolete types of valves, showing the growth of the present models, was a feature of this stand.

A range of transmitting valves was also shown, including the high power water or oil-cooled types as used at Daventry. The usual amateur transmitting types were also to be seen, together with one which promises to be of interest to many of our readers. This is the D.E.T.1 and it is said to be the first dull-emitter transmitting valve to be produced. It is rated at 40 watts, the filament current being 1.9 amps, at 6 volts, the normal anode voltage being 1 000. The valve is fitted with a special low-capacity cap, consisting of a bakelite base, with four pins, one at each corner of the base.

On Messrs. Autoveyer's stand were to be seen samples of many types of Western Electric valves, including the well-known power valve. The cathode ray oscillograph (described in our issue of September) was also exhibited.

The Dubilier Condenser Co., apart from the usual broadcast apparatus, were showing many types of transmitting condensers, including new types suitable for amateur transmitters. These are in porcelain cases, about 5 in. high and 3 in. in diameter.

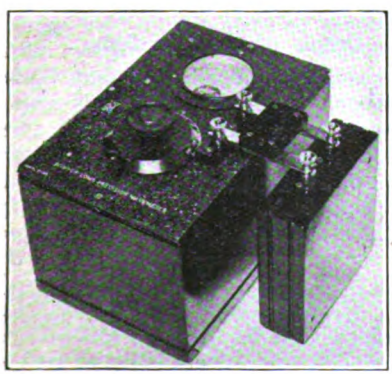
Some well-made standard variable condensers were also to be seen, together with banks of standard fixed condensers which are intended for laboratory use. On this stand we noted also a buzzer wavemeter, using plug-in coils, and supplied with calibration charts.

Other firms showing buzzer wavemeters were Messrs. Burndept and Messrs. Bowyer-Lowe. That produced by the former is known as the "Ethophone" buzzer wavemeter.

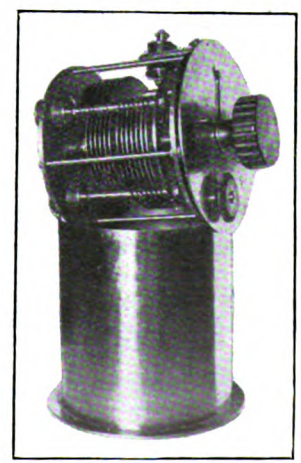
The Bowyer-Lowe precision wavemeter is fitted with interchangeable coils for different ranges, and a Weston thermo-ammeter is incorporated for the purpose of indicating resonance.

The Marconiphone Co. have now produced a cheaper model of the "Ideal" L.F. transformer, known as the "Junior Ideal" and priced at 25s. It is said to give a very good amplification curve. Good curves are also shown by the new Pye and B.T.H. transformers.

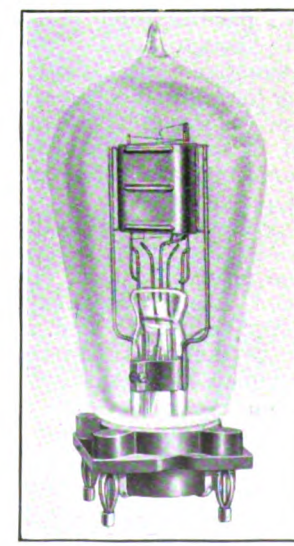
The tendency in the case of variable condensers has been to produce geared or slow motion models, and almost every firm is showing either an actual geared condenser or a "vernier" dial intended for use on an ordinary condenser.



The Bowyer-Lowe wavemeter which is provided with separate coils for various ranges.



One of the Dubilier standard laboratory variable condensers.



Of interest to all transmitters—the new "Osram" dull-emitter transmitting valve being made by the M.O.V. Company. The price is £5 5s.

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Rectifiers for High-Tension Supply.

Part III: Rectification by Gas Conduction.

By R. Mines, B.Sc. **[R355·5**

The present instalment deals with Gas-Conduction Rectifiers of atmospheric-pressure type.

I.—The Electrical Nature of a Gas.

OUR atmosphere (or in fact any gas in a chemically inactive state) consists of a crowd of molecules—and according to the Kinetic Theory of Gases these molecules are continually moving about, hitting each other and rebounding, with what is known as "thermal agitation," to an extent depending on the temperature of the gas. This is the normal condition, there being in general no changes in the chemical of electrical state of the molecules.

The latest theories concerning the structure of the atom (the unit, of different kinds, from which molecules are built) indicate that it consists of a positively-charged "nucleus" (which contains practically the whole mass of the atom) surrounded by a number of electrons (*i.e.*, unit negative charges) revolving around it in various orbits. These "orbital electrons" are thus bound to the nucleus by electrostatic attraction, just as the planets, while revolving in their orbits, are bound to the sun by gravitational attraction. This analogy is strikingly close—for the relation between the size of an electron and the size of its orbit (or in fact the "size" of, or space occupied by, the atom) is of the same order as in the case of the planets in the solar system.

When two atoms in their motions approach each other, their outermost electrons come the nearest to each other, and because of their like charges experience an electrostatic repulsion; and, subject to exceptions to be described, this repulsion is communicated to the atomic systems by the internal forces that make these systems stable. The result is an "elastic collision" (the rebounding mentioned above), similar to that which takes place between two billiard balls. In a like manner a single electron may collide elastically with an atom, rebounding with its original kinetic energy but with an alteration in its direction of travel.

II.—The Gas as an "Insulator."

It is evident from the above description that in its normal state a gas is composed of neutral molecules, and that unless by some means "carriers" of electricity are brought into existence a permanent gas behaves as an insulator.

Actually, however, this statement is not strictly true (neither is it for liquid or solid "insulators") for Coulomb in 1785 showed that a charged body gradually lost its charge even when supported by the best solid insulator procurable, due to conduction of the electricity through the surrounding air (later C. T. R. Wilson repeated this result while eliminating any possibility of leakage due to the solid support by means of a guard-ring device. This phenomenon, known as the *dark discharge*, is now attributed to the continuous generation of "ions" or carriers of both signs by ionising radiations from radioactive substances in the earth. But the magnitude of the effect is very small—it is calculated that about six ions are generated in each cubic centimetre of the atmosphere in every second due to this cause; whereas a current of one ampere consists of a flow of electronic charges at the rate of about 16×10^{18} per second.

III.—Origin of Positive Ions.

We have said that an electron may make elastic collision with an atom; this holds true as long as its velocity of approach does not exceed a certain critical value. Above this point, however (which is known as the "resonance potential"* for the gas in question) the stabilising forces of the atomic

* The velocity, or rather the kinetic energy, of a moving electrified particle is most conveniently expressed in terms of the potential difference though it would have to fall to acquire this velocity if starting from rest, *i.e.*, in terms of the amount of *potential energy* that is converted into the kinetic form.

The kinetic energy is equal to $\frac{1}{2}mv^2$, where m is the mass of the particle and v is its linear velocity.

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system can no longer stand up to the impact—the moving electron is capable of disarranging the atomic structure, causing one of the electrons in the atom to change its orbit.

A further increase in the velocity of an electron may cause it to disrupt the atom with which it collides, expelling one or more of the orbital electrons from the parent atom. In this condition the atom is said to be "ionised," since it is positively charged (having *lost* some *negative* charge) and will therefore behave as an "ion" or carrier of electricity.

For every gas there is a series of "ionisation potentials"* corresponding to the detachment of one, two, etc., electrons; the first one only need concern us here, since the removal of only one electron from an atom constitutes it an effective carrier.

The sudden change in position of an orbital electron, either from one orbit to another or in complete expulsion, involves a change in its potential energy—this accounts for the absorption of kinetic energy from the impacting electron arriving from outside. After an inelastic collision there is always a tendency for the atom to return to its original condition, by the return of the displaced electron to its original orbit, or by the "recapture" of any free electron that may come within the sphere of influence of the ionised atom—there will always be an electrostatic attraction between the two. Such process is called "recombination."

When such a return of an electron takes place, its newly-acquired potential energy is given out in the form of electromagnetic radiation. The return is frequently accomplished in a number of steps, the electron falling into a succession of possible orbits—thus the radiation occurs in pulses. It is the frequency of this radiation, not its intensity, which is determined by the amount of energy transformed at each step: and this is dependent on the orbits concerned, and therefore on the atom's structure; hence it is characteristic of the kind of matter.

The frequency of the radiation is often within the limits of visibility, so that regions where ionisation and recombination are taking place may be seen by the light emitted. (By the use of a spectroscope, which analyses the frequencies present in this light, it is possible to determine what kinds of matter are taking part in the process.)

IV.—The Gas as a "Conductor."

Evidently the first effect of establishing a potential difference across a space between two electrodes filled with gas (*i.e.*, applying an electric stress to the gas) will be to cause all positive ions to fall down the potential gradient towards the negative electrode, and also negative ions to "fall" up the gradient, to the positive electrode.

Thus an electron, for example, will accelerate until a collision takes place, either with a gas molecule or with the positive electrode—in the latter case it is merely absorbed, but in the former if the electric stress is sufficiently great it may cause ionisation. In this event there result at least two electrons (in general having now only a small velocity), and a positive ion; and if the electric field where these two electrons find themselves is still high enough the process will be repeated for each of them. The action is thus cumulative, and if the field is of fairly uniform strength over the path between the electrodes (as between two parallel plates or between two spheres of somewhat the same size) an unstable condition results and a *spark* snaps across. We shall presently see that the spark discharge is actually a little more complex in nature than the description so far given would indicate.

On the other hand when the surface of one electrode has a radius of curvature very small compared with the distance between them (for example a fine wire, or a sharp edge or point), a stable form of discharge may be produced. The effect of thus shaping the electrode surface is to cause an excessively strong field in the immediate neighbourhood of this surface, at the expense of that over the remainder of the space. It must be remembered, though, that the effect of the motion of ions in such a field is to even it up Thus with a moderate-sized wire, say 0.02 in. in diameter, mounted centrally in a tube about 1 in. in bore, sparking will take place more readily than any other form of discharge (excepting of course the "dark" type—provided, however, that the distribution of

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and the potential energy is equal to Ee, where e is the charge on the particle; then if E is the P.D. as defined above, these quantities may be equated, from which we discover that $E = \frac{1m}{2e} v^2$; and e being constants for the same kind of particle.

* The first ionisation potential of air is 17 volts, and of helium 25 volts.

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potential remains sufficiently uneven, then, although cumulative ionisation may take place in the vicinity of the fine wire or point beyond this region the ions produced can proceed only relatively slowly—the conduction here being of the dark type. The ionised region is usually visible by the emission of light—from this follows the name *Glow Discharge.*

V.—The Brush Discharge.

We have considered so far the effect of accelerating only the electrons. The positive ions, being also charged particles, are accelerated by the same electric field, but the velocity they acquire is several thousand times smaller in proportion in fact to their greater mass. It is proved, however, that they too can produce ionisation when their velocity is high enough—to achieve this result in air at atmospheric pressure requires an electric stress of about 30 kilovolts per cm. They also possess this other useful property—that when they bombard a metal surface with sufficient energy they release electrons from it, though they themselves may become buried in it.

Therefore, if the over all P.D. is further increased with the sharply curved electrode arrangement we find a sudden increase in the current carried by the discharge, and this latter assumes an appearance of bright lines of light radiating from the sharp electrode (generally tending to fix on irregularities of its surface)—the appearance reminds one of brush bristles, and from this resemblance it is named.

VI.—The Corona Rectifier.

It will be obvious that if the sharp electrode is made positive, then positive ions will have their direction of motion away from it; whereas if it is negative they will be able to bombard the electrode surface. Hence, whether or no the critical potential at which positive ions can release electrons from a metal surface is less than that at which they can ionise gas molecules, the fact stands out that with the sharp electrode negative the positive ions have two chances of assisting the ionisation, whereas with it positive they have only the one. In other words current will pass more easily in one direction than in the other, and this asymmetry can be used for rectification.

The usual form of apparatus for this purpose consists of a hollow cylindrical conductor, with a fine metal wire stretched as accurately as possible along its axis. An alternating P.D. is applied between these two electrodes, and when it is adjusted to a suitable value, it is found that an appreciable current will flow *via* the brush discharge, at the peak of that half wave during which the wire is negative, but not during the other half wave.

The rectification is not "perfect," but the efficiency obtainable is good considering the nature of the phenomena on which it depends. Davis and Breese,[1] using a tube nearly 2 in. in bore and a wire 0.008 in. in diameter, obtained rectified currents up to 0.12 amp, but the alternating P.D. used was 8 kilovolts. Thus the apparatus is not likely to be of much interest to radio workers other than in connection with the higher-powered transmitting stations.

VII.—The Spark Discharge.

It has been noted earlier that the processes of ionisation by collision are cumulative; and that when the electric stress between two electrodes is fairly uniform over the intervening space, if it is high enough to cause ionisation at all, the discharge grows very suddenly into the spark form. Such uniformity of field exists between parallel plates for example, or between any electrodes for which the radius of curvature is not very small compared with the distance between them.

The condition is also set up in the Corona Rectifier, or with a sharp point and a plate, if the P.D. across the apparatus is raised too far; for as the value increases, the region wherein ionisation is taking place extends over more and more of the available space, and when it reaches the second electrode the discharge changes to a spark or even to an arc.

VIII.—The Air Blast Rectifier.

The establishment of a spark means an increase in the current many hundredfold—there being a plentiful flow of ions of both kinds, travelling, of course, in opposite directions. For it must be remembered that the positive ions are material particles; and it found that a discharge of the heavier kind may be prevented by a strong blast of air, for any positive ions formed have the motion of all surrounding air particles in

[1] *Journ. Amer. I.E.E.*, Vol. 36, p. 153, 1917.

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addition to that due to the electrostatic force, and so may be carried away from the path of the discharge and prevented from contributing to the ionisation.

Rectification may be effected by use of this "blowing out" effect in the following way:—

The air-blast or jet is directed so that the direction of motion of the air is *along* the path that would be followed by the discharge. The tendency then is for positive ions to travel with the jet, and as long as this direction coincides with that of the electrostatic force upon them, they are able to ionise by collision in the manner described; the negative ions have to travel against the blast, but since they are mostly electrons this is an easy task, both on account of their higher acceleration under the electric force and on account of their minute size which enables them to pass easily among the relatively cumbersome atoms.

When the relation between the directions of the air blast and of the electric stress is opposite to that described above, no current can pass (other than a slight leak or dark discharge of electrons) because any positive ions formed are blown back on to the positive electrode.

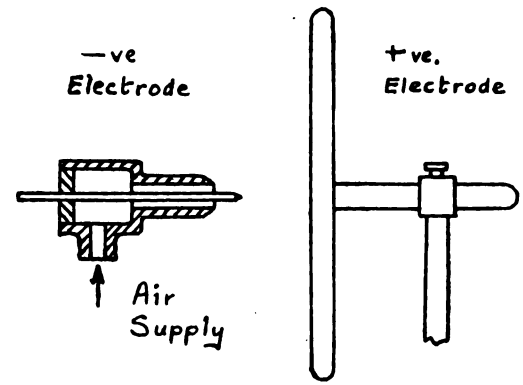
Thus if an alternating P.D. is applied to such a system, a relatively heavy discharge will pass in one direction but not in the other.

IX.—A Practical Form of the Apparatus.

A form of apparatus developed by some American workers consists of a metal rod $\frac{1}{16}$ in. diameter with the end coned, facing a flat plate, the gap being adjusted to about $\frac{5}{8}$ in. The diameter of the plate is made relatively large (*e.g.*, 4 in.) to preclude the possibility of the discharge travelling to its edges; preferably the edges are rounded. The rod electrode is arranged to project concentrically a short distance from a hole about $\frac{3}{16}$ in. diameter in an air chamber; the air jet emerges from this hole as a nozzle, a blower being connected to the chamber which will supply air at pressures up to 10 lbs./in.^{2}.

It is found experimentally that the pressure of air supplied to the chamber controls the completeness of the rectification obtained—this is to be expected, since it determines the velocity of the jet and therefore the effectiveness with which positive ions are prevented from travelling from the plate to the point. In one case a pressure of about 1 lb./in.^{2} was sufficient to produce maximum rectification of the current; excess over this amount, besides being unnecessary, caused irregular operation.

This form of rectifier is at a greater disadvantage even than the corona type in that it is not possible to work it on lower alternating P.D.s than a few kilovolts—since a P.D. of this order of magnitude is necessary to jump the gap before any power is available for output. With a reservoir condenser



The arrangement of electrodes in the air-blast rectifier.

(capacity about 0.001μF) connected across the load, 100μA of rectified current was obtainable, the D.C. output pressure being 15 kilovolts.

X.—Effect of Gas Pressure.

Experiments have been conducted with the electrodes enclosed in an air-tight vessel; different gases were used, and the blast pressure was raised in some instances as far as 200 lbs./in.^{2}. With air a maximum efficiency of rectification (this includes the H.T. transformer) of 75 per cent. was reached at about 160 lbs./in.^{2} Ammonia gave 85 per cent. at 100 lbs./in.^{2}; with this gas continuous operation of the rectifier for 10 hours without attention was attained. It is supposed that under the action of the discharge the gas is chemically decomposed into nitrogen which is inert, and nascent hydrogen which is a powerful reducing agent that effectively prevents burning of the electrode faces.

AUTHOR'S NOTE.—A great deal of space in this article has been taken in attempting to give a clear explanation of the mechanism of gas conduction, because this is an essential introduction to an understanding of the operation of rectifiers that are to be described in future articles.

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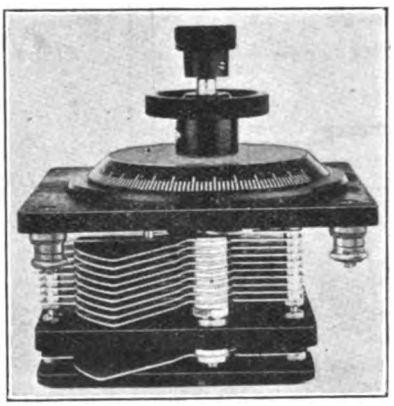
Apparatus Tested. [R·009

Two Dubilier Components.

The "Vanicon" Square Law Condenser. [R381·3

MESSRS. THE DUBILIER CONDENSER CO., LTD., of Ducon Works, Victoria Road, North Acton, London, W.3, are now making a series of "Vanicon" square law variable condensers with verniers. We have recently tested one of these, having a nominal maximum capacity of .000 5μF.



The compact and well-designed "Vanicon" condenser.

The condenser is built up with ebonite end-plates, and the vanes are of aluminium. The spacing between the plates is quite small, with the result that the component is very compact, the depth below the panel being only 2¼ in., which, it must be remembered, includes the vernier. The instrument can be used either for panel or table mounting, the latter being facilitated by the use of squared ebonite end-plates.

The moving spindle is of ¼ in. brass, with adequate bearings, and the movement of the plates is very "sweet."

Positive contact to the moving plates is made by means of a phosphor-bronze spiral, so that trouble due to intermittent contact is eliminated. Two large terminals, mounted underneath the upper end-plate, serve for purposes of connection.

On test we found that the minimum capacity was 16μμF, the vernier added another 30μμF, and the total capacity was .000 567μF, being thus slightly over the rated capacity. The power factor, although not actually measured, appeared to be normal to good.

The condenser is evidently of sound design and construction. The prices for nominal capacities of .000 25μF, .0005μF and .001μF, are 17s. 6d., £1 2s. 6d., and £1 7s. 6d. respectively.

We understand that another model, embodying several new features, is being designed, and it will probably be reviewed in due course.

The Dubilier-Mansbridge Variometer. [R382·7

Another Dubilier product which we have recently tested is the Dubilier-Mansbridge variometer.

This variometer has been designed with a view of increasing the compactness without sacrificing efficiency. To this end the coils are of the flat "D"-shaped type, two being fixed, and two moving, the latter being rotated by a standard knob and dial.

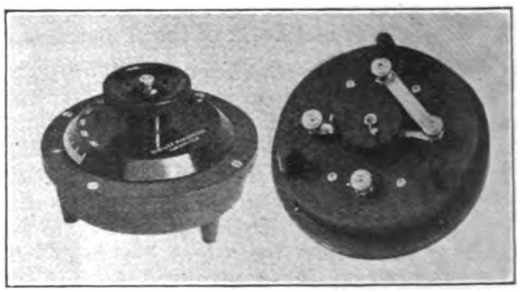
The makers have certainly succeeded in making the instrument compact, for the depth behind the panel is barely 1½ in., and the overall diameter is only 3¾ in.

The coils are completely enclosed in a moulded case, and three feet are provided for use if it is not desired to mount the variometer behind a panel.

The ends of the fixed and moving sets of coils are brought out to four terminals, and straps are provided so that the coils may be connected in series or parallel. Connection to one end of the moving set is made by a spiral of phosphor-bronze. For the other connection, a spring washer rubbing on a plate is relied upon.

For our tests we connected the coils in series. We found that the inductance varied from 65μH at the minimum to 300μH at the maximum. Shunted with a .0003μF condenser, this would result in a range of about 265 to 565 metres (neglecting the self-capacity of the coils). This range might be expected when used with a full size P.M.G. aerial, without an additional condenser in parallel.

We found the self-capacity over the whole range to be about 5μμF, which is a good low figure. The resistance at the minimum was 11 ohms, and that at the maximum 19 ohms, in each case at a frequency



This novel variometer contains coils of the flat "D" shaped type.

corresponding to 400 metres approximately. This is rather higher than that of some of the coils now on the market, though not to any considerable extent.

On calculation, the power factor was found to be .03 and .02 at the minimum and maximum respectively. This again is somewhat greater than many coils, but not seriously so.

Considering the extreme compactness of the component, the electrical efficiency is good.

The component is supplied in a box, complete with drilling template and a leaflet of diagrams, price 12s. 6d.

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The Marconiphone Variometer. [R382·7

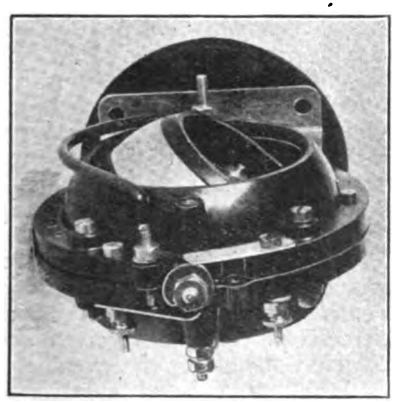
The Marconiphone Company, Ltd., of Marconi House, Strand, W.C.2, are selling a rather novel variometer, which covers a wide wave-length range. For this purpose the windings of the variometer are used in parallel for the lower range, and in series for the higher. The change-over from the parallel to the series position is effected without a separate switch, and is quite automatic.

The dial is engraved from 0° to 360° From 0° to 180° the windings are in parallel, but as the 180° position is reached, an ingenious cam and leaf contact switch (seen in our illustration) comes into action and switches the windings, so that from 180° to 360° they are in series. It is not practicable to obtain an absolutely smooth change-over at the 180° position. There is bound to be some break in the wave-length at this point. The great advantage is the automatic switching.

The two windings are on moulded formers, and very close coupling is obtained, which gives a good wave-length range, although the power factor is likely to be increased to some extent.

The variometer was tested in our laboratory, and following is a résumé of the results obtained. The inductance ranged from about 75μH (microhenries) to 2 430μH, so that with a full-size P.M.G. aerial a wave-length range from less than 300 metres to just over 1 600 metres is obtained, and thus both the lower broadcast band and the high-power station's wave-lengths are covered.

The H.F. resistance varied from 10 to 30 ohms, and the self-capacity from 25 to 30μμF. The power factor as obtained from these results ranged from .011 to .024.



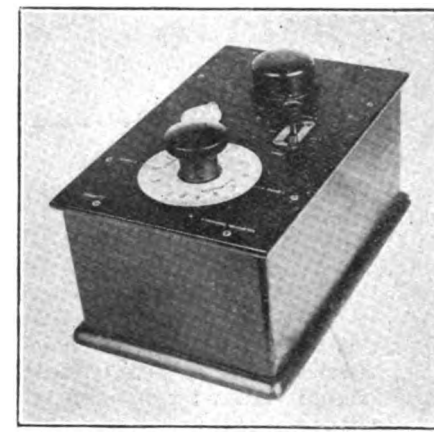
By means of a cam switch, the coils of the Marconiphone variometer are switched in series and parallel.

Needless to say, the component is particularly good from the point of view of mechanical strength and finish, the movement of the rotor being very smooth, and the electrical connections between the two coils being quite sound. Connections to the instrument itself are made to two small terminals.

For those who use variometer tuning and wish to cover a wide wave-length range without trouble, this variometer should prove particularly serviceable. The price is 16s.

A Standardised Buzzer Wavemeter. [R384·1

Messrs. Burndept Wireless, Limited, of Aldine House, Bedford Street, Strand, W.C.2, have just produced a wavemeter known as the Burndept Ethophone Wavemeter. It is of the well-known buzzer type, with two ranges—200 to 500 metres and 800 to 2 000 metres. Two coils are provided,



The two-range buzzer wavemeter described herewith.

wound on ebonite tubes and waxed, and tuning is performed with a Burndept standard precision condenser of .000 5μF capacity. A switch which places the condenser across either coil at will is provided, thus giving the two ranges. An "Off" position is also available.

The buzzer, which is of a well designed and substantial pattern, is operated by a small 1.5 volt dry cell, which is easily replaceable. The instrument is mounted on an ebonite panel, which is fitted to a polished mahogany cabinet, the overall measurement being approximately 10½ ins. by 6½ins. by 6¾ins.

The problem which had to be faced by the makers in producing these instruments was to combine accuracy with low cost. Individual calibration had thus to be abandoned; instead, the scales of the condensers are all similarly engraved to read directly in metres. To make this possible, all component parts have to be manufactured and adjusted by precision methods.

On test, against one of our standard wavemeters, the sample submitted to us showed up well. At the lower end of the scale we found the error to be about 3.5 per cent. in the case of the lower range and about 5 per cent. for the higher range. Further up the scale, the accuracy was within 2 per cent.

The price of the wavemeter is £6 6s., and considering the good finish and accuracy, it is to be recommended to those who are requiring an instrument of this type.

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Long-Distance Work.

By Hugh N. Ryan (5BV). **[R545·009·2**

UNTIL last year, the "active" and "inactive" periods for DX work were clearly defined, and recurred annually. The work was ruled almost entirely by weather conditions, and so the division was simply that in winter DX work was done and in summer it was not.

Nowadays, however, summer no longer disrupts long-distance contact, and we have just reached the end of our first year's continuous work. It is therefore of interest to notice whether there is still a slack period, and if so, when.

I think there is no doubt that, as far as this country is concerned, work falls off somewhat about September. It is not easy to say whether this is due to purely wireless conditions, or whether it is just because the average amateur takes his holiday at this time. Perhaps the reason is a psychological one, in that the amateur forsakes wireless to get the best out of the departing summer, and will return as soon as it has departed; whatever the cause, all reports this month indicate a falling off in quantity of work, although contact with all countries is easily being maintained.

The only difference in conditions which I have myself been able to notice is that the Americans (north and south) report bad QRN more often than usual, and slightly more is sometimes noticeable here.

I do not think that any new country has been worked during the month, but communication with South American countries and the MacMillan ships has been more frequent than hitherto.

In response to my last month's request for further observations on 45-metre fading phenomena, many stations have reported exactly similar results to those I mentioned, and an extremely interesting addition comes from 5NJ (Belfast). He finds that powerful London stations can hardly be read in Belfast at 6 a.m. and remain extremely weak until 7.15 or later. He can hardly hear any English stations between midnight and sunrise. Reinartz, operating WNP, tells me that American signals fade out about 2 a.m. (G.M.T.) for two hours, while British signals are still OK. WNP's own signals become somewhat weaker soon after this time. Mexican 1B says that my own signals become much weaker to him just after sunrise in England, coming back to their usual strength as soon as the sun is well up.

The more powerful London stations are working quite regularly. 2KF works New Zealand most mornings, often on phone. 5LF works nearly every morning from 5 to 6.30 (G.M.T.), and has worked Mexican 1B and a number of A's and Z's during the month.

6LJ is in fairly regular operation, mostly working Americans, and has also worked z4AR. 6TM has worked a2CM, and a number of New Zealanders, including one (4AS) who had not worked Great Britain before. 5BV's broken mast has been replaced, and a number of new stations worked, including WNP and Mexican 1B, as well as New Zealand.

6RM has conducted some interesting work with NKF, the American Navy's experimental station, in addition to working with other more distant countries. 6QB has reduced his power to 1.8 watts, and has been working chiefly with home stations. He has heard, among other New Zealand stations, one (z2AQ) who has not, I think, been heard here before. 6YK has been working on very low power, and has been reported as R6 in Stuttgart, with ¾ watt input, on 96 metres. 6VP is now using his full 10 watts, and has been received strongly in most parts of Europe on 90 metres.

Mr. N. Guy, of Pinner, a keen receiver and prospective transmitter, has carried out some extremely fine reception on a very simple receiver. He has received 40-metre New Zealand signals in the evening, a feat shared, I believe, only with d7EC, and he has heard a3JU, a station not hitherto reported here.

2CC has a new 45-metre set working now. He has worked all American districts except 6 and 7, as well as NKF and both the MacMillan ships, WNP and WAP. 5KO has worked a number of American stations from his new station at Newcastle, but he is not using the power of his old Bristol days.

I understand that 2OA is working more on paper than "on the air" at present, but

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2TF is keeping the Scottish end up, working with U.S.A. on 23 metres.

6TD is still the leading station in Wales, though 6US is shortly returning to the work. 6TD works U.S.A. regularly, and at the time of writing has, I think, just got through to New Zealand. 6US is to be expected back as soon as he has succeeded in drilling the requisite number of glass panels without breaking them.

Two stations are now working in Northern Ireland, both in Co. Antrim. 5NJ has worked with u1PL, this being the first Irish-American contact. 5NJ was using under 20 watts, and QRN was very bad in America at the time. The first communication between Ireland and Norway was accomplished by 6MU, who has worked LA1A with 4 watts.

The Cambridge Society's scheme, which I have mentioned before, should be in working order soon after this appears. They hope to establish a listening centre, which will listen to and report upon tests from any station who desires it. The listening will be done by competent amateurs who are thoroughly *au fait* with our work, although not themselves transmitters.

Many conflicting reports have reached this country concerning the amateur position in the Irish State Free. It appears that no amateur transmitting permits have yet been granted. There are many competent, but isolated, experimenters there who feel that they would be in a better position if they could get together. I hope that readers in Saorstat Eireann, who are interested in the question, will unite, as we should all like to have transmitters in every part of the British Isles.

The most interesting item of foreign news is the work of our nearest Continental neighbours with the Antipodes. The leading French station in this work is 8WAG, who has been working Australia and New Zealand for some time. He recently worked z2AE when the latter was only using 28 watts input. This is probably a record for low-power trans-world work.

Belgian 4YZ has worked with z2AC, using 65 watts input. This is the first B-Z contact. 7EC is the only Danish station working. He still works Porto Rico 4SA to schedule, and has also worked Brazil 1AB. A station signing y7XX has been working for some time in Jugo-Slavia, and has worked a number of British stations.

I have received from Major Raven-Hart, the pioneer Chilian amateur (ch9TC), an interesting account of amateur activities in Chile. 9TC was until recently the only station working there, but several more have started recently. ch2LD has worked U.S.A. and New Zealand with 5 watts, and ch1EG has worked China and Britain on 50 watts. (These powers are American "tube" ratings, and not actual input powers, which are probably about four or five times as much.) 9TC himself works mostly on 275-metre phone, but tests with Argentine MA1 from 21.15 to 21.45 (G.M.T.) on about 85 metres on Tuesdays and Fridays. He has been heard in this country, and would welcome further reports.

Next month, when there are more stations working and American QRN has lessened, there will probably be more to report. Perhaps we shall soon work the American West Coast and the inland parts of Canada, which work is certainly overdue.

Please let me have next month's reports by the 10th.

Round the World by British Wireless.

By Major Wm. Coates Borrett (C1DD). **[R545·009·2**

THIS old Empire of ours, on which the sun never sets, can now claim to be the Empire on which amateur DX wireless never ceases.

For years it has been the hope of the Canadian amateurs that some day they would be able to relay messages and make tests completely round the world by British amateur wireless. And, having that idea in view, the Division Managers of the five Canadian Divisions of the American Radio Relay League, when they met in conference in the city of Winnipeg during the month of December, 1924, made plans to hold Trans-Canadian tests every Wednesday night, in order to get all Canadian stations linked up, so that eventually the Maritime Division could get in touch direct with Great Britain

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and the Vancouver Division with the New Zealanders, who, in turn, could establish contact with the home country *via* Australia and India—thus making an "all red" route round the world to handle British messages.

We already knew that the English stations were making world's records every morning by working direct with our brother "hams" in New Zealand, but our idea was to organise the whole Empire into a series of small jumps, which should be more reliable.

To start the thing going we set aside the wave-length of 125 metres for Trans-Canada and inter-Empire amateur communication. We have had Trans-Canada tests every Wednesday night on this wave, with the great majority of stations in every district taking part; and now it is a simple matter to pass messages back and forth from East to West. These Wednesday night tests take place at nine-thirty Pacific coast time, which is five-thirty A.M. Thursday, G.M.T. It is a splendid time for British stations to do some good DX work and link up with our western stations direct. Although we all send in the vicinity of 125 metres, we listen from 100 to 135 metres in case any other British stations happen to be on at the time.

While the Division Managers were speeding home by train (Winnipeg is four days' run by train from the writer's home at Dartmouth, Halifax, Nova Scotia), the rest of the boys were "digging in" for all they were worth; and to my great joy I found that on 4th December Mr. Joseph Fassett (1AR, of Dartmouth, Nova Scotia) had been in direct touch with NZ4AA, and had won the honour of being the first Canadian to work New Zealand direct—in spite of the fact that he is the greatest possible distance in North America from New Zealand.

This was just the thing to spur the rest to greater efforts to get QSO New Zealand to further our scheme, especially as 1AR was on the east coast. On 10th December Mr. Arthur Crowell of 1DQ, again of Dartmouth, N.S., also reported having been in touch with NZ4AA. Next the west coast got in, and station 5BA, of Vancouver, operated by H. T. Libby, got in touch with NZ4AG and 2AC on 11th December. The east coast again linked up when the writer (1DD) worked NZ4AG for over an hour on 15th December. It is also believed that 5GO of Vancouver has since worked NZ.

It may interest British readers to know that 5GO is operated by Mr. Chang, a Chinese boy in Vancouver, who is one of the leading amateurs in Western Canada. It is understood that he is in Canada for the special purpose of studying wireless and soon is to return to his native country to take an important part in wireless development there.

In addition to this super-DX of over nine thousand miles from our east coast and over six thousand miles from our west coast, we have been keeping in touch with the Mother Country, so that our scheme is working itself out very well. The only drawback has been the fact that most of the English stations, after calling "ARRL," listen in that terrible band of QRM 75-80 metres, and in most cases we have been forced to QSY down from 125 to get them to answer us. However, this is doubtless through not knowing where we are calling and also on account of the New Zealand and Australian stations working around 85-90 metres.

One step farther was made in the world-wide relay by British radio on the night of 7th January when G2NM, working on about 100 metres, took part in our regular weekly relay, and test messages were handled from London, Eng., to Halifax, through the Maritime Division and in relays right across Canada to Vancouver, B.C.

Another relay, which took short cuts, but was really along the lines of our scheme, took place on 16th December or thereabouts, and, as usual, that gentleman who is always doing things ahead of schedule—Mr. Joseph Fassett of 1AR—had the honour of showing the rest of us how it should be done. He took a message from NZ4AG and passed it to G5MO, who, in turn, passed it to G2NM, to whom the original message was addressed. G5MO got the surprise of his life when 1AR handed him the message, and if only it had come from Australia in the first place, our entire object would have been accomplished: communication round one side of the earth.

On behalf of the Canadian amateurs the writer invites all British stations to take part in these relay tests, and would suggest that the English stations undertake the organisation of the eastern route from England to Australia *via* as many British countries as possible; and some day we will be able to start a message from London and pass it right around the world and back to London within twenty-four hours.

The Canadians are ready: QTC?

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"Wipe Out." [R147

Some notes on a popular fallacy with regard to the effect of induced local oscillations on incoming signals.

THIS article is written in the hope that it will help to clear up some of the misconceptions which at present seem to be prevalent on the question of "wipe out." For those who are interested and require further mathematical or experimental proof of what is contained in this article (and considerably more besides), I would refer them to a paper by Dr. E. V. Appleton in the *Proceedings of the Cambridge Philosophical Society* (Vol. 21, p. 231), "Automatic Synchronisation of Triode Oscillators."

The general view of some writers would appear to be that if a weak C.W. signal is being received in a wireless receiver, and if a strong local heterodyne be used, then the induced local oscillations will "wipe out" the incoming signal. This is entirely at variance both with practice and theory, as shown in the above-mentioned paper. Of course, if the local oscillations are strong enough to sweep over the complete range of the receiver's first valve characteristic there would, to put it loosely, be no further room for the incoming signal; but this is a special case which we need not consider here.

That "wipe out" exists is undoubted; it has been observed by many, but what actually takes place is not so widely known. Suppose two triode oscillators, A and B, are coupled together and that a detector circuit be placed near by. Let the frequency of A be made to approach that of B and gradually varied through the resonant point of B, and let A be the stronger oscillator. Let the frequency of A be n_a, and that of B be n_b. As n_a approaches n_b a very high note will be heard in the detector telephones. This note gradually becomes lower as n_a gets nearer n_b, until finally the note suddenly disappears altogether. When n_a has passed n_b the note again appears, low in tone, and rising as n_a departs from n_b. This is the well-known heterodyne reception.

The "silent space" (when n_a is very close to n_b) is not due simply to the note in the telephones being below the audible limit, but is due to the fact that the *stronger oscillator draws the weaker oscillator into step with itself.* This becomes readily apparent if the two oscillators are strong and are fairly tightly coupled, for the beat note in the telephones disappears noticeably before the audible limit is reached. This phenomenon is termed "automatic synchronisation," or, more loosely, "wipe out."

Now the crux of the matter is that this effect is not directly due to any property of the two oscillatory circuits, but is due to the fact that the triodes associated with these oscillatory circuits cause them to have varying decrements. Thus, if in an oscillatory circuit there are two oscillations present, "wipe out" can only occur due to the interaction of the sources of these two oscillations.

Let us apply this to the case of signals received from a distant transmitter. In the receiver there are two oscillations present, one due to the distant transmitter and another due to the local heterodyne. Let the local oscillations be of large amplitude compared to the distant—as is usually the case in heterodyne reception. Then, at first sight, it would appear that there would be "wipe out," but this is not the case. Remember that it is the interaction of the sources of oscillation that produce "wipe out." Thus it is the interaction between the local oscillator and the source of the signal—*i.e.*, the transmitter—that we must consider.

Now, the transmitter is obviously much more powerful than the local oscillator, and will have much more effect—*via* the receiver—on the local oscillator than will the local oscillator on it—also *via* the receiver. Hence the signal can draw the induced local oscillations into step with itself, but the reverse process is out of the question.

As a matter of fact, the measurement of the region over which synchronisation, or "wipe out," takes place is a direct measurement of signal strength, since the width of the silent space is directly proportional to the signal strength and inversely proportional to the strength of the local oscillations. In this case, experiment coincides with theory to within 15 per cent.

Thus, there need be no fear when receiving very weak signals that a relatively strong local oscillator will "wipe out" the incoming signals, and the local oscillator can be kept relatively strong, optimum heterodyne reception being ensured.

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For the Esperantists.

Distordado. [R800

Pritraktante la demandon pri rezistanca (aŭ ŝoka) kupleco, kontraŭ transformatora intervalva kupleco, ni penas eksplodigi popularan—kaj seriozan—sofismon.

PARTO III.

AVERTO DE FABRIKISTO.

EN la du antaŭaj partoj ni pritraktis la elekton kaj utiligon de valvoj. Nia nuna tasko estas trakti pri intervalva kupleco.

Sed antaŭ ol tion fari, estas necese dediĉi ankoraŭ pli da spaco pri la valva demando, pro letero kiun ni ricevis de la *General Electric Company*. Esence, la letero estis averto de la fabrikisto de la valvoj (kiu supozeble *devus* ja scii), ke la agado de ni rekomendita, kiu ofte postulas la uzon de altatensia voltkvanto supernorma, povus efiki malbone la valvan vivon.

Ni treege bedaŭras sciiĝi pri tio, sed ni tute ne ŝanĝas nian opinion. Nia celo estas montri, *kiel eviti distordon*, kaj ni montris, ke estas necese uzi altpotencan valvon por la lasta ŝtupo. Se la valvofabrikistoj avertas nin, ke ne estas eble funkciigi iliajn valvojn ĝis la plena kvanto de ties filamenta emisio, pro tio, ke la bezonata altatensia voltkvanto domaĝos ilin, la sola kuraco estas uzi eĉ pligrandajn valvojn; ekzemple, L.S.5 anstataŭ 625, 625 anstataŭ 606, k.t.p.

Efektive, tamen,—ni ĝojas diri—ni *ne* trovis, ke la anodaj voltkvantoj sugestitaj de ni, almenaŭ por transformatora kuplo, naskos ian malbonon.

LA INTERVALVA KUPLECO.

Oni ordinare parolas pri tri ĉefaj specoj de malaltfrekvenca intervalva kuplo: transformatora, ŝoka, kaj rezistanca. Tamen, rilate al distordado, estas efektive nur du: tiuj sen krada kondensatoro, kaj tiuj kun.

Treege bedaŭrinde, ĉar ni deziras esprimi nian honestan opinion tiurilate, ni devas defaligi idolon, kiun oni nunmomente adoras tra la lando.

Estas nuntempa modo supozi, ke rezistanca kuplo estas ja la plej uzinda, pro tio ke, malgraŭ la perdo de forteco, oni tute certe ne ricevos distordadon. *Laŭ nia opinio, tio estas absoluta sofismo.*

Certe la plimulto de transformatorekuplitaj aparatoj tute ne estas perfekta; sed kaj teorie kaj praktike estas kaŭzoj kial la rezistance aŭ ŝoke-kuplita aparato estas eĉ plimalbona, krom se ĝi estas treege lerte desegnita.

La necesega diferenco estas, kiel ni jam sugestetis, la ĉeesto de la krada kondensatoro. Kiam ajn la krado ricevas pozitivan ŝarĝon, estas elektrona kurento, kiun ni povas konsideri kiel ordinaran kurenton de krado al filamento. Ĉi tiu kurento povas kompletigi sian cirkviton nur pere de la krada rezistanco; tial, post haltigo de la dumtempa impulso (kiu envenis pere de la krada kondensatoro), la afero staras kiel ĉe Fig. 1, kun kurento fluanta tra la rezistanco, kaj negativa ŝarĝo ĉe la krado.

Tio daŭras ĝis ekvilibro estas laŭgrade restarigita per fluo de la kurento tra la rezistanco. Dumtempe, la kontrolo de la valvo estas renversita; eble la krado estas tiom negativa, ke ĝi ne funkcias ĉe rekta parto de sia karakterizo, kaj distordo okazas.

Distordo ja okazos, se oni permesos, ke la krado fariĝu pozitiva en amplifikatoro sen krada kondensatoro, sed ĝi ne estas tiel severa. Memoru, ke ĉi tia distordo estas ĝuste sama esence kiel la rektifa ago de valvo. Ĝuste kiel la krada rezistanco kaj kondensatoro instigas al efika detektado, tiel ĝi produktas distorditan amplifadon, escepte se oni treege zorgas.

DEFINITIVAJ BEZONOJ.

Ekzemple, antaŭnelonge ni eksperimentis je amplifado laŭ pligranda skalo, ol ordinare. Ni uzis 300 voltojn anodajn kaj 30 voltojn kradajn ĉe L.S.5[1] a valvo. La kvalito estis tutbona, kvankam iomete distordita

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ĉe akra orelo; la miliampermetro estis meze, kvankam ne tute, trankvila. Konforme al ies sugesto, oni anstataŭigis la lastan transformatoron per rezistanca kuplo, altigante la altan tension ĝis 400 voltoj, je kiu ĝi emisiis ĉirkaŭ 25 miliamperojn.

Je ĉiu laŭta tono, la miliampermetro resvingiĝis al 15 miliamperoj, kaj (kiel oni atendis) la kvalito estis aĉa. Ĉar ni posedis nur baterion 450-voltan, ni ne povis kontroli praktike la teorian indikon ke—40 voltoj kradaj kaj 600 altatensiaj estas bezonataj.

Resume, ŝajnas ke, dum por transformatora kuplo krada potencialo de nur duono de la *meza* modulo sufiĉas por tre bonaj rezultoj, kun ŝoka aŭ rezistanca kuplo, oni devas aranĝi por la *maksimuma* modulo ĉe laŭta tono, kun konforma altigo de alta tensio. Plue, oni devas zorgi pri la valoroj de la kradaj kondensatoro kaj rezistanco kaj anoda rezistanco, kiuj ofte estas malĝustaj en aparatoj kaj kupliloj vendataj nuntempe.

Konsiderante unue la anodan rezistancon, ni devas kompromisi inter malmulta efikeco, se ĝi estas tro malgranda, kaj troa alta tensio, se tro granda. Ŝajnas ke valoro de duoblo de la anoda impedanco de la valvo estas justa kompromiso, sed oni devus klare scii, kio ja estas la anoda impedanco. Kelkaj el la pli popularaj Britaj valvoj havas valorojn proksimume jenajn :—

	Omoj.
"R" kaj aliaj valvoj por ĝenerala uzado (helaj aŭ malhelaj)	20 000
Malaltfrekvencaj (malhelaj kaj duonhelaj)	15 000
Altfrekvencaj (malhelaj kaj duonhelaj)	25 000
625 kaj similaj altpotencaj valvoj	5-10 000
625b kaj similaj "alt-μ" altpotencaj valvoj	20 000
625a kaj similaj "malalt-μ" altpotencaj valvoj	20 000

Rilate al ŝok-kuplita aparato, estas grave ke la impedanco de la ŝoko, eĉ por la plej malaltaj aŭdfrekvencoj, estu granda, kompare kun tiu de la valvo. Oni bezonas proksimume 100 henriojn; tio estas, induktanco kiel tiu de la sekundario de bona intervalva transformatoro. La mem-kapacito devus esti malalta.

La kondensatoro devus esti granda; sed ĉar, kiam la krado neatendite pozitiviĝas, la rezultanta distordo pligrandiĝas laŭ la grandeco de la kondensatoro, estas kutime, ke ĝi ne estu tre granda. Tamen, ĝi certe ne estu malpligranda ol .05μF, kaj se la krada rezistanco estas malalta, kiel priskribota en la proksima paragrafo, estus plibone.

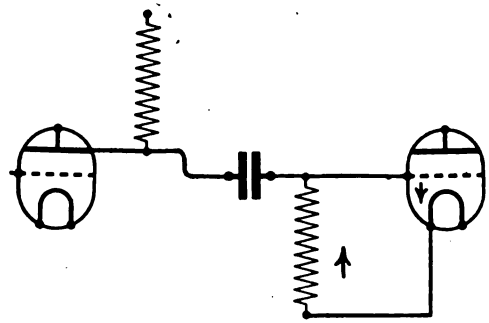

Fig. 1.

Kiel ĉi-supre sugestite, la kutima krad-rezistanco estas treege tro granda. Altvalora krad-rezistanco treege pligrandigos la eblecon de distordo. Same, tro malalta rezistanco kaŭzas perdon de forteco. Ĉi tiu gazeto jam pritraktis la problemon laŭ teknika vidpunkto. Sufiĉas diri, ke la plej bona valoro estas ĉirkaŭ 250 000 omoj.

RESUMO.

Per ĉi tiaj antaŭzorgoj—malgranda anoda rezistanco kaj krada rezistanco; grandaj kondensatoro, altatensio, kaj krada potencialo—oni povas ricevi superbonan kvaliton per rezistanca amplifikatoro. Kiel ĝi komparas kun transformatora kupleco? La sola avantaĝo estas, ke la rezistanca amplifikatoro funkcios de 50 cikloj supren; dum, ĉe la plej bonaj transformatoroj, la transformatora amplifikatoro kredeble ne funkcios ĝis 200 cikloj. Sed nun venas alia punkto. Ĉu nuntempa stacio de la Brita Brodkasta Kompanio sendas tiujn ĉi malaltajn frekvencojn (50 ĝis 200 cikloj) je preskaŭ plena forteco? Se jes, ĉu la nuntempa laŭtparolilo reproduktos ilin? La aŭtoro opinias mem, ke oni devas respondi "*ne*" al ambaŭ demandoj, kaj ke tial la rezistanca aŭ ŝoka amplifikatoro ne havas veran avantaĝon *nunmomente* por kompensi sian malefikecon.

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Letters of interest to experimenters are always welcome. In publishing such communications the Editors do not necessarily endorse any technical or general statements which they may contain.

Proposed Institute of Radio Engineers.

The Editor, E.W. & W.E.

SIR,—Allow me to concur with your remarks in "Editorial Views," in the September issue. Wireless has become a large family and must have a house of its own. It must cease to be a lodger under the roof of the I.E.E. if real progress is to be made. The I.E.E. are to be congratulated on fostering wireless in its infancy, but I feel that to label a wireless engineer as a "chartered electrical engineer" will falsify the status of electrical engineering and bring blushes to the cheeks of the purely wireless man.

That the new Institute should consist of qualified wireless engineers is a highly important feature. A fundamental education up to matriculation standard, backed by a good knowledge of higher mathematics such as algebra, analytical geometry, differential and integral calculus and differential equations, with a thorough drilling in electricity and magnetism—high-frequency A.C. work being most important—and wireless telegraphy and telephony should meet the case. Acoustics and other sciences kindred to wireless should also be considered, and practical experience must, of course, play an important part.

We must not, however, overlook the fact that most wireless men are self-taught and many men holding high positions in the wireless world commenced as amateurs.

H. GAMBRELL.

36, Manor Road,
Rugby.

American Science—A Reply.

The Editor, E.W. & W.E.

SIR,—On page 521 of your issue of May last appears a letter by Mr. D. V. Onslow, under the heading "Power Factor Measurements." Mr. Onslow states amongst other things that "the British spend £50 on research apparatus and £1 000 on thinking, and get results, while Americans spend £1 000 on apparatus and £50 on thinking, and get lost."

From the tone of Mr. Onslow's letter I am inclined to think that he knows very little about American research; has he heard of the U.S. Bureau of Standards? And does he know that the results obtained in this national laboratory are embodied in publications which are sold to anyone by the U.S. Stationery Office at the bare cost of printing?

Speaking about methods of making measurements, has Mr. Onslow ever heard of the American society for testing materials, or seen the results of their researches, which are published annually?

Again, does Mr. Onslow know that the results of all U.S. Government research departments, including those in agriculture, engineering, meteorology, and many other branches of science, are available to the public; and that the various scientific societies always have their material available for use by the engineers of the world?

It is to be hoped for the sake of the Electrical Research Association, of which presumably Mr. Onslow is a member, that this gentleman obtains more facts before writing his reports than he did before writing the letter now under reply.

As an engineer trained in England and America, I am glad to know that leading engineers of England, as evidenced by their own statements, do not hold the same opinion as your correspondent, but give credit ungrudgingly to our American cousins for the very fine work which they produce.

Is it too much to ask that Mr. Onslow spends one shilling in gathering facts before he spends a penny stamp in disparaging the work of his brother engineers?

C. R. RUSSELL, M.Sc., M.I.R.E., A.M.I.E.E.
162, Heaton Street,
Christchurch,
New Zealand.

The "R.I." Transformer Curve.

The Editor, E.W. & W.E.

SIR,—On principle I rather take exception to the "R.I." advertisement on page iii. in EXPERIMENTAL WIRELESS, September issue.

Surely the transformer that amplifies *all* frequencies equally is the perfect transformer? There have been lengthy articles on this very subject in E.W. & W.E. from time to time.

Again, it has come as a shock to me to learn that the reason why "the 'R.I.' curve is right" is because the "transformer amplifies overtones more than the fundamental." Surely it is best to amplify all frequencies equally! Unless there was some new factor discovered by "R.I.," one would be inclined to think the "R.I." curve was far from right; and, in any case, the lower curves shown at least get down to about 1 000 p.p.s., and even at a loss of amplification would be the more pure.

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Whilst I am anxious and willing to purchase and am proud of British wireless goods that *are* good, I consider this advertisement not only misleading, but unfair to transformers that do more nearly approach perfection.

E. A. ANSON (2OA).

Portseton.

Station News.

The Editor, E.W. & W.E.

SIR,—Will readers please note that my address is now changed from 10, Lake Road, Lytham, to "Highcroft," Park Lane, Burnley, Lancs. All QSL cards and reports of any kind are answered and are very welcome.

In addition, some of your readers may desire to send a card or a report to the following French stations—8TOK, 8ROR or 8ZEB.

If they do, they may send them *via* the above address. There is no necessity to enclose a stamp. The three stations referred to always reply to QSL cards and to reports of any kind.

J. C. HARRISON (5XY).

Burnley.

The Editor, E.W. & W.E.

SIR,—The P.M.G. has allocated to me the call sign 6CI in place of my old one, 2APG, which was issued with my licence for an artificial aerial. I would be very pleased to receive any reports on my transmissions which at present are on 90 metres.

BRIAN W. WARREN.

19, Melville Road,
Coventry.

The Editor, E.W. & W.E.

SIR,—I shall be glad if you will publish my call sign and address in your next issue.

They are 6KA and 58, Ulverston Road, Upper Walthamstow, E.

KEITH HARDIE.

The Editor, E.W. & W.E.

SIR,—I should be grateful if you would publish the following :—

My call sign is 2UD; wave-lengths 150-200 metres and 440 metres; power 10 watts; C.W. and telephony.

I shall be using an underground aerial, and will welcome very much all reports, which will be answered.

A. ACLAND (2UD).

"Kenwell,"
Boxley Road,
Chatham, Kent.

The Editor, E.W. & W.E.

SIR,—I should be very glad if G2NU and G5ZHC would communicate with me at the address below, as I have cards for them from NoPM.

R. A. WEBBER (G2BDQ).

8, Theresa Avenue,
Bishopston, Bristol.

The Editor, E.W. & W.E.

SIR,—Will you insert in your journal a notice to the effect that I transmit almost daily on 23 metres (C.W.) and should be glad of reports. All cards answered.

PERCY BRIAN, M.Sc. (G6GW).

79, Lakey Lane,
Hall Green, Birmingham.

The Editor, E.W. & W.E.

SIR,—The call sign 2VS, formerly the property of a transmitter in the Norwood district, has now been allocated to me. Telephony and C.W. transmissions will be carried out on wave-lengths of 23 and 150-200 metres.

Detailed reports will be greatly appreciated, and all QSL cards acknowledged.

JOHN D. R. HAMMETT.

88, Fairlop Road,
Leytonstone, E.11.

The "Red Seal" Loud Speaker. [R376·3

WE have recently tested the above loud-speaker, which is manufactured by Sexton Barnes, Ltd., of 61, Borough Road, London, S.E.1. It is known as the "Red Seal" model No. 10. In size it is intermediate between the "baby" and the full-sized instrument, and is designed for use in an average-sized room.

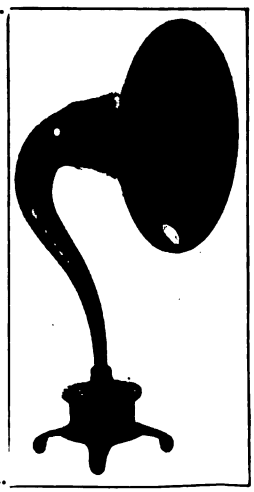
As will be gathered from our illustration, it is very graceful in design, the finish being crystallised black, the terminals, etc., being nickelled.

Before we tested the instrument it appeared to us that the sound conduit was on the small side and that the makers had apparently sacrificed efficiency to the graceful appearance of the instrument. On test, however, we found that our expectations were entirely unfounded. The strength of signals was only slightly (*i.e.*, about 10 per cent.) below our standard, which, considering the size of the instrument under test, is particularly good. We found that it was not easily overloaded and would deal with at least twice the power which would be required an average-sized room.

The tone was all that could be desired providing the instrument was not overloaded.

The price of this efficient little instrument is 45s.

The "Red Seal" loud-speaker described herewith is graceful in appearance, and gave surprisingly good results on test.



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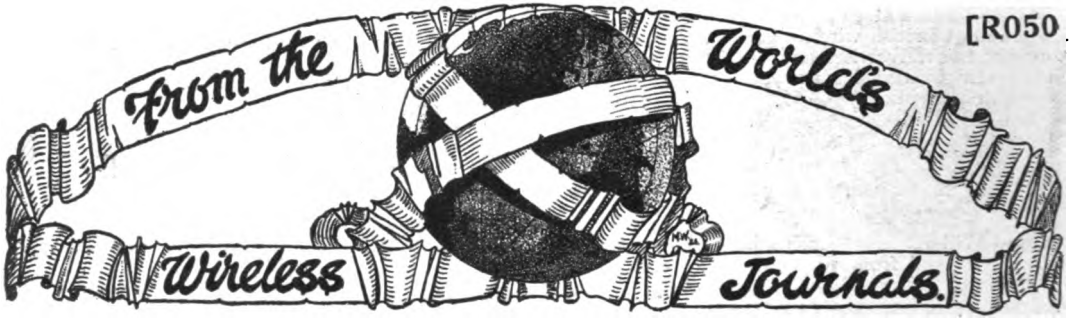

[R050

R300.—APPARATUS AND EQUIPMENT.

R344.—Un Poste d'emission de 200 kW pour Essais de Triodes.—Dr. Balth. van der Pol and K. Posthumus (*Onde Elec.*, Aug., 1925).

A description of an experimental plant for work with water-cooled oscillator valves up to 200 kilowatts. The type of valve used has a cylindrical anode of chrome-iron alloy which also constitutes the envelope round which water may flow for cooling purposes. The upper part of the valve is of glass which is sealed to the metal part. Filament and grid leads to external connections are sealed through the glass portion. The cathode consists of two parallel hairpin-shaped filaments taking a heating current of 80 amperes at 17-18 volts. The valve has an internal resistance of 3 000 ohms, a μ of 40 and operates on anode voltages of 8 000 to 12 000. The high-tension supply is derived from 3-phase A.C. fully rectified by six water-cooled diodes of similar construction to the oscillator. The oscillator circuit supplies H.F. energy to an artificial aerial consisting of a loose-coupled inductance, a condenser and a resistance. The latter has to be capable of dissipating some 150 kW as heat and is composed of a number of carbon bars in a rack. Carbon has the advantage of showing comparatively little skin-effect and obviates the necessity for corrections on this account when calculations are made on the electrical energy dissipated in heating it up. A large part of the paper is given up to theoretical analysis of the conditions for efficiency in a valve generator. As is generally known, a triode excited about the mid-point of a substantially straight characteristic cannot have an efficiency exceeding 50 per cent. as a D.C.-to-H.F. converter. Greater efficiencies are obtained by biasing the grid negatively, so that normally no anode current would flow, and by giving the grid a series of positive pulses each lasting a small fraction of a cycle. As analogy to this method of excitation the case of a pendulum is considered where the pendulum is kept swinging by correctly-timed pulses of short duration. The relation of efficiency and power output to the phase angle θ during each cycle over which the excitation persists is worked out. As θ varies from 0 to 2π the theoretical efficiency varies from 100 per cent. to 50 per cent. while the input power varies from 0 to 50 per cent. An efficiency of 100 per cent. cannot be attained in practice but with the apparatus described efficiencies up to 87.5 per cent. have been obtained. It is interesting to note that the grid biasing was effected by a grid condenser and leak, the latter consisting of carbon lamps to the value of 1 800 ohms. The grid current is stated to be 1.5 amps, giving a negative bias of 2 700 volts. The expenditure of 4 kilowatts in grid-current seems high even for so large an installation, but these are the figures clearly stated in the paper.

R100.—GENERAL PRINCIPLES AND THEORY.

R131.—Uber Elektronenbahnen in Trioden.—Balth. van der Pol. jr. (*Zeitschr. f. Hochfrequenztechnik*, Vol. 25, No. 5).

An article dealing with the electronic paths in triodes. In the first part of the paper the distribution of potential and charge are compared in the cases of a heated and unheated diode with plane electrodes. It is shown that at a certain potential-difference between cathode and anode the field at the anode remains the same as at the cold cathode if the heated cathode is removed further from the anode by about a third of the original distance. Next the electrostatic field in a cylindrical triode is examined more closely. The amplification factor μ is defined as the ratio of the filament-grid and filament-anode capacities. It is shown further that the total current i_a+i_g which the incandescent filament loses is entirely a function of $V_a+\mu V_g$, where V_a and V_g are the potentials of anode and grid; there being two exceptions, however. The first occurs at very small values of space-current when the grid lies within the cloud of electrons surrounding the filament, this space-charge distorting the electrostatic field. The second marked distortion of the field occurs in a certain region where V_a is less than V_g; the explanation offered is that a secondary space-charge of primary electrons is formed in the vicinity of the cathode by electrons which have passed twice through the meshes of the grid. Characteristic surfaces for i_a and i_g and a complete set of V_g, i_a, curves are discussed with the aid of stereoscopic models. Irregularities of the characteristics become apparent when the triode sends out the very short waves first noticed by Barkhausen and which are attributable to the double space-charge. The phenomenon of secondary emission, which plays an important role in three-electrode valves, is then studied. The ratio of the number of secondary electrons per primary electron is found by suitable interpretation of the characteristics with the aid of the law which holds for the case when no secondary electrons occur. Special oxide-coated anodes were constructed which released 20 and more secondary electrons per primary electron. Lastly, the total heating up of the electrodes was investigated and it was found that the electrode with the higher potential was less heated and that with the lower potential more heated than would follow from the product of current and voltage for the electrode considered.

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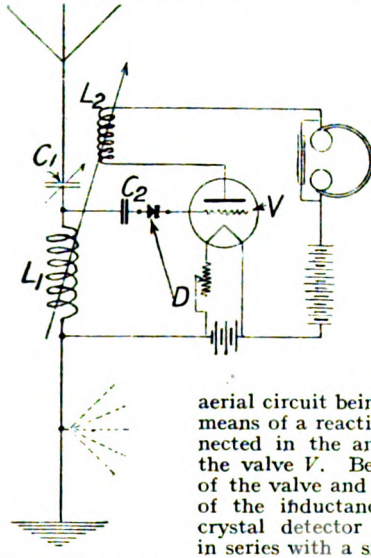
(The following notes are based on information supplied by Mr. Eric Potter, Patent Agent, Lonsdale Chambers, 27, Chancery Lane, W.C.2.) **[R008**

A CRYSTAL-VALVE CIRCUIT.

(*Application date*, 14*th March*, 1924. *No.* 232,390.)

A very useful combination of a crystal and valve is described in British Patent No. 232,390 by A. W. Sharman. The object of the invention, it is stated, is to obtain the maximum sensitivity from a crystal detector. The inventor states that the efficiency of a crystal detector is considerably lowered by the current passing through it. Accordingly the scheme shown in the accompanying illustration is adopted.



An ordinary tuned aerial circuit $L1$ $C1$ is shown, reaction on the aerial circuit being obtained by means of a reaction coil $L2$ connected in the anode circuit of the valve V. Between the grid of the valve and the upper end of the inductance there is a crystal detector D, connected in series with a small condenser $C2$. It is stated that the capacity of this condenser should be very small, and that the insulation should be exceedingly high, thus preventing any steady direct current from flowing through it. The inventor states that the detector functions by virtue of variation of electrostatic potential, which is conveyed to the grid of the valve and amplified. This is, of course, the case of "pure potential rectification" described by Colebrook in his recent series in E.W. & W.E., and shown by him to be quite effective.

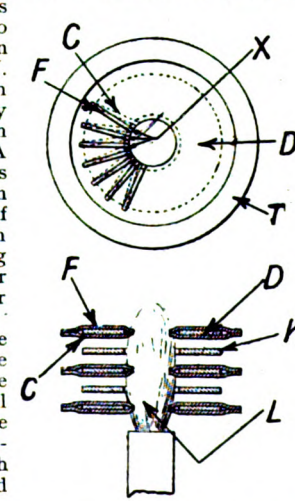
A THERMO-ELECTRIC BATTERY.

(*Application date*, 26*th February*, 1924. *No.*233,810.)

A rather interesting invention is described in the above British Patent by Fullers United Electric Works, Limited, and A. P. Welch. The thermo-electric junction has been known for many years, and hitherto its applications have been in connection with the measurement of minute voltages or temperatures. Recently the "thermo-former" has been placed on the market with the idea of providing a direct current supply of low voltage suitable for operating valve filaments, the initial supply of energy being obtained from the domestic lighting supply.

The above invention relates to one such device, and a particular form of construction is represented diagrammatically in the accompanying illustration. It is well known that if certain dissimilar metals be placed in intimate contact and the point of contact heated, a certain potential difference will be developed. Thus, if two strips of dissimilar metals, such as iron and constantin, be welded together, and the junction heated, a voltage of the order of 0.02 volt will be produced.

A combination of metals of this description is made use of in the particular example illustrated, and it will be seen that a number of junctions consisting of strips of iron F joined to strips of constantin C are joined at X. A number of such pairs are radially disposed around an asbestos disc D. A number of these discs are arranged as shown in the lower half of the illustration, each disc of elements being separated by another disc K of asbestos or similar material.



Thus it will be seen that if a flame L passes through the centre of the discs all the junctions will be heated, and the voltages produced at each junction will be added together, since the junctions are arranged in series. One hundred junctions would give a voltage of about 2 volts, and by using strips about an inch wide it is possible to obtain a current as great as 1 ampere. It is essential however that a temperature difference should exist between the opposite ends of the strips, and for this reason the outer ends of the thermo-junctions are arranged in a tube T through which

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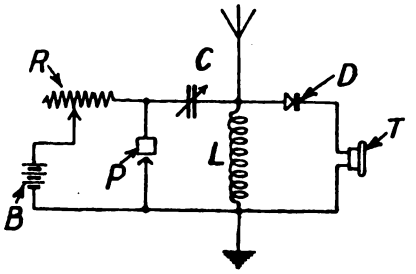
water may be circulated, in order to cool the strips.

We should imagine that the device would be extremely useful where only gas is available.

OSCILLATING CRYSTALS.

(*Application dates, 9th April, 1924, and 24th July, 1924. No.* 236,648.)

The above British Patent, No. 236,648, granted to H. J. Round and N. M. Rust, contains some very interesting details. The invention relates to a method of obtaining negative resistance effects



with a crystal combination as well as actual oscillations. The specification includes very comprehensive instructions, giving actual values of the components, which will be quoted later, but no suggestion is given to account for the manner in which the scheme functions.

Referring to the accompanying illustration, it will be seen that the aerial is tuned by an inductance *L*. An ordinary crystal detector *D* and telephones *T* are provided, which are connected across the inductance in the usual manner. The negative resistance device consists of another crystal detector *P*, which is connected through a variable condenser *C* across the aerial inductance, a variable resistance *R* and a battery *B* being shunted across the detector *P*. The ordinary aerial and detector circuit are quite normal, the variable condenser *C* being of the order of about 0.000 8μF, though under working conditions the value of this condenser may be between 0.000 1μF and 0.000 25μF. The resistance *R* can be varied between 1 000 and 12 000 ohms, and the 50-volt battery *B* is tapped every 1½ volts, the negative pole being connected to the contact point.

It is stated that the best results are obtained with the highest value of the resistance and about 50 volts from the battery, higher voltages tending to burn the point. The best results so far as the crystal is concerned were obtained with "arzenite," which is the trade name for a crystal which is practically a pure zinc oxide. Other crystals, such as silicon, zincite, tellurium, magnetite and iron pyrites may be employed. The negative resistance effects can be increased if a spot is fused on the arzenite crystal by connecting the positive pole of a 100-volt supply main and forming an arc between it with a pointed carbon electrode. Instead of the crystal detector *P*, a combination consisting of a catwhisker and an oxidised film can be used. The film can be produced by forming an arc with the plate as one electrode. Thus a zinc plate can be coated with white zinc oxide. It has been found, however, that by subjecting a coated zinc plate to a subsequent treatment with the arc a reddish-brown oxide is formed, and at the point marking the junction of the two oxides it is possible to obtain oscillations on wave-lengths as short as 600 metres, whereas with an ordinary coated plate it is only possible to obtain oscillations with the longer wave-lengths. With an ordinary crystal, however, it is possible to get the device to function on broadcast wave-lengths, and the scheme as outlined should be of particular interest to experimenters.

THE MAGNESIUM "GETTER."

(*Convention date, France, 22nd March,* 1924. *No.* 231,194.)

A method of evacuating a valve or similar discharge tube is claimed in the above British Patent by the Compagnie Générale de Telegraphie Sans Fil, and relates to the use of magnesium. The patent deals essentially with methods of igniting magnesium. When the valve is assembled a small piece of magnesium is included in the vicinity of the plate, and the valve is then exhausted.

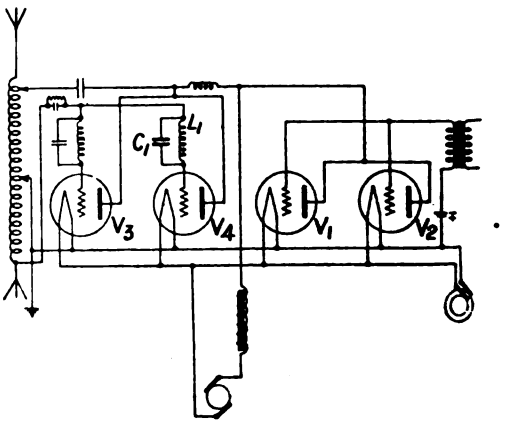
The magnesium is ignited by passing a current through the grid sufficiently intense to heat it to the required temperature, and in another modification the magnesium is attached to the plate and ignited by the heat radiated from the grid to the plate.

The advantage of the method, of course, lies in the fact that no high voltage has to be used between the filament and the plate.

SHORT WAVE TRANSMISSION.

(*Convention date, U.S.A., 22nd January,* 1924. *No.* 228,159.)

A rather interesting short wave transmission circuit is described in the above British Patent by the Westinghouse Electric and Manufacturing Company, and R. L. Davis. The circuit shown, it will be noticed, is an ordinary choke control or constant current modulator system, connected to two oscillators. It is stated that the object of the



invention is to overcome some of the troubles which are associated with the centre tap type of coupling, in which, it is stated, it is usually found necessary to employ a large number of turns in the grid circuit in order to produce oscillations, resulting

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in very high grid voltages being produced, and general instability of the system. Referring to the illustration it will be seen that the valves $V1$ and $V2$ are ordinary modulators, while the valves $V3$ and $V4$ are the two oscillators connected across an inductance L, a centre tap filament connection being employed.

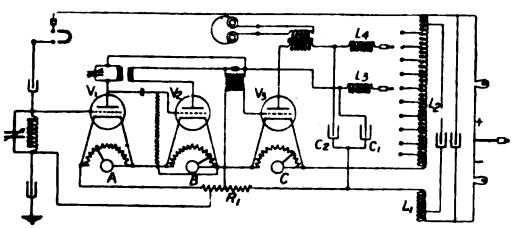
Instead of taking the grid lead direct to the grid, each grid is connected through a trap consisting of an inductance $L1$ and a condenser $C1$. It is stated that the introduction of a filter in this position is found to increase the stability of the system, avoids parasitic oscillations, and, in addition, enables a very much lower grid voltage to be employed.

No explanation is given to account for the manner in which the scheme operates, but we should imagine that it is somewhat comparable with the use of a tuned circuit in place of the usual high frequency choke which is employed in the anode circuit of a shunt feed supply to an oscillator system.

DIRECT CURRENT SUPPLY.

(*Application date*, 21st *May*, 1924. No. 236,702.)

Another system for utilising the domestic supply for broadcast receivers is described in British Patent No. 236,702 by P. B. Frost. The scheme utilises direct current mains, and the voltage for the filaments is obtained from resistive chokes $L1$ and $L2$. The filament current is further reduced



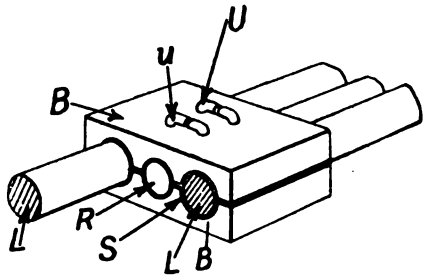
by a resistance $R1$, which is also utilised for obtaining grid bias for the valve $V3$. The filaments are run in series, and are controlled by variable resistances A, B and C. The choke $L2$ from which the high tension supply is obtained is tapped. Further smoothing for this purpose is obtained by means of chokes $L3$ and $L4$ and condensers $C1$ and $C2$.

The specification is very detailed, and describes the particular arrangements of the chokes and resistances as shown in the diagram. There is nothing particularly novel about the whole idea, and the invention really lies in the actual combination and arrangement of the device shown, the particular values of which, together with the method of arrangement, are described in great detail.

FILAMENT LEAD SUPPORTS.

Convention date, U.S.A., 15th December, 1923. *No.* 226,196.)

The British Thomson-Houston Company, Ltd., and R. B. Prindle describe in the above British Patent a method of supporting the filament leads in a high power valve. Referring to the accompanying illustration, which shows one of the supporting devices, it will be seen that two filament



leads are held between clamps consisting of two rectangular portions provided with grooves.

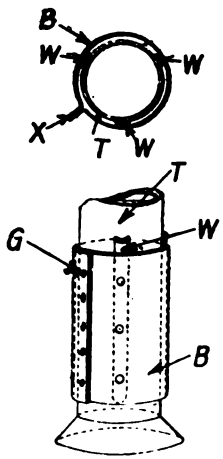
The two filament leads L are clamped between two blocks B provided with longitudinal grooves. The blocks may be of metal and an insulating sheathing S is included to prevent the two leads from becoming short-circuited.

It will be noticed that there is a third rod. This rod R is for the purpose of supporting the filament leads. The two blocks are held together by means of "U"-shaped staples U. The rod R is provided with two transverse grooves or slots, through which the "U"- shaped pins can pass. It will be obvious that these transverse slots prevent the rod from rotating, and the pins maintain the clamp secure in position.

ELECTRODE SUPPORTS.

(*Application date*, 3rd *May*, 1924. *No.* 236,692.)

A method of supporting the electrodes in high power transmitting valves is described in the above British Patent by The Mullard Radio Valve Company, Limited, C. F. M. Hayes and L. Grinstead. Referring to the accompanying illustration it will be seen that the electrodes are supported by means of a metal band B, which is placed around a re-entrant tube T. The two edges of the band are bent up as shown at X, and are welded together at G. It will be noticed that the band is a very easy fit over the re-entrant tube, and is held in position by means of wedges W, which are pushed between the collar and the tube, and are then spot-welded to secure them in position.



In another modification of the invention, the wedge may actually constitute the legs supporting the electrodes. This arrangement is shown in the lower half of the illustration.

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"E.W. & W.E." Calibration Department.

Valve Wavemeters.—Between 60 and 20 000 metres.

Fees.—For a single range, 2s. For each additional range, *i.e.*, swing of condenser over its full scale, add 1s.

Valve wavemeters must be accompanied by the actual valve to be used.

Information required.—Filament, anode, and grid volts to be used; minimum and maximum wave-lengths expected on each range.

Buzzer Wavemeters.—Between 100 and 6 000 metres.

Fees.—For the first range, 1s., each additional range, 6d. (For "range," see above under valve wavemeters.)

Information required.—Voltage required for buzzer if battery not enclosed in meter; minimum and maximum wave-lengths expected on each range.

Fixed Condensers, not more than .002μF, 9d., tested at R.F. Larger, tested at audio-frequency, 1s.

Variable Condensers, 1s. plus 3d. for each position tested.

Inductors, Fixed, Air Core (we do not test iron-core coils). Coils between 50 and 50 000μH tested for inductance and self-capacity, 2s. 6d.

Inductors, Variable.—Each tapping or position on a variometer will be tested as a separate coil.

Fees.—As above.

Condensers and Inductors can be tested for H.F. Resistance. For further particulars see pages 276 and 277 of our February issue.

Resistance, D.C., measured to the following accuracy; below 1 ohm, 1 per cent.; 1 to 10 000 ohms 0.1 per cent.; above 10 000 ohms, 1 per cent.

Fee.—9d.

Resistance, H.F.—Resistors of 1 to 30 ohms, approximately non-reactive, can be tested at any one desired radio-frequency between 2 000 and 15kC (150 to 20 000 metres).

Fee.—2s. 6d.

Voltmeters, D.C., of maximum reading 2 to 250 volts. If the scale is blank, only light pencil graduations will be put on.

Fee.—6d. plus 3d. for each reading.

Information required.—Approximate maximum voltage.

Ammeters, D.C., of maximum reading 10 micro-amps to 5 amps. Conditions as for voltmeters.

Voltmeters, H.F., Moullin type, complete with plate ammeter, can be tested at any one radio-frequency between 2 000 and 20kC. Limits of voltage, .1 to 10 volts.

Fee.—1s. plus 3d. per reading.

Information required.—Exact steady voltage to be applied to anode and grid, reading on plate ammeter with no applied H.F. voltage, whether voltmeter is of grid-leak type or not.

Milliammeters, H.F., complete, or thermo-junctions. Limits of current 1 to 500 milliamps.

Fees.—As for H.F. voltmeters.

Information required.—Approximate maximum current. In case of separate thermo-junctions, D.C. resistance of indicating instrument to be used with them.

EXPERIMENTAL WIRELESS & The WIRELESS ENGINEER.

COUPON for OCT., 1925.

Calibration Department.

139-140, Fleet Street, London, E.C.4.

Sender's Name .....

Address .....

.....

Apparatus sent ..... *Date* .....

DETAILS OF TESTS.

For fuller particulars of the tests and information we require, attention is drawn to pages 276 and 277 of the February issue of E.W. & W.E.

In spite of our previous requests, apparatus continues to come in insecurely packed. The packing case should be *screwed*, not nailed, since this enables the same case to be used when returning the instrument.

All remittances should be large enough to cover the cost of returning apparatus by registered post.

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EXPERIMENTAL WIRELESS & The WIRELESS ENGINEER.

VOL. II. NOVEMBER, 1925. No. 26.

Editorial Views.

Valve Rectification.

WE commence in this issue the publication of a second most important paper by Mr. F. M. Colebrook, B.Sc., A.C.G.I., D.I.C. This paper deals with valve rectification in the same complete manner as this author's paper on "Crystal Rectification," published in E.W. & W.E. for March, April and May last, and in our opinion the two papers will form by far the most important contribution to the subject that has yet appeared.

Although the mathematical part of Mr. Colebrook's work is not really exceptionally difficult, there may be readers who are content to accept his very important conclusions without actually checking his arguments; and for these we are preparing a short summary of the paper, as non-technical as possible.

We only mention one point here. Mr. Colebrook confirms, both theoretically and practically, our personal view that grid rectification is not to be recommended for telephony.

Valves and their Names.

We do not, as a general rule, like to repeat ourselves, but for once we propose to do so, in the effort to call attention again to the question of valve nomenclature. At the moment of writing, we have no access to our records, but even speaking from memory, we can give sufficient examples to show the absurdity of the present position. For example, Marconi-Osram valves in common use comprise "L.S." Nos. 1 to 5, and "D.E." 2 to 8—perhaps now that Marconi and Osram are separating one of them will rename them! Among Mullard valves are a ".3" and a ".06" series, an "S" series, a "DFA" series, and a new valve called the "PM4." Many of these are practically identical with the M-O types, but neither the letters nor the figures have any correspondence with one another nor with the purpose of the valves. B.T.-H. have a "B" series, and Ediswan "ARDE" "AR06," and "PVDE" series, and the same remarks apply. Cossor valves have their own keys, and so have all the other makers. This in spite of the fact that most of these firms work together, and that a definite nomenclature has already been suggested.

We are glad to see that the new Burndept valves are actually marked according to our suggested scheme, a considerable improvement in it having been made by them. What we now suggest is that, since the other valve-makers are apparently too indifferent to users' convenience to make any step, our readers should consistently use the new nomenclature, order valves accordingly, and so gradually force a reasonable scheme on the makers.

As a reminder, the scheme suggested is as follows: every type of valve has a 3-figure number, of which the first figure as rated

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filament volts, and the last two rated filament current. Thus the popular "60-milliamp" type is a 306, and the old "R" a 465.

In our original scheme, we used final small letters *a* and *b* to indicate valves of exceptionally low or high μ. But we now suggest a slight elaboration of the Burndept scheme, *for use when desired.* According to this, letters before the number denote magnification, as follows:—

HH: extra high; for μ of 20 or thereabouts.
H: high; for μ of 9—14.
HL: medium; for μ of 6—9.
L: low; for μ of 4—6.
LL: extra low; for μ of 2 or thereabouts.

These letters also correspond to the present popular habit of recommending high μ valves for H.F. and low μ for L.F. amplification.

Thus the valve sold by M-O as D.E.5b, and by Mullard as DFA4, should be called in either case HH625 if we wish to note its μ; otherwise simply as 625 type.

Perhaps if readers will help, we can in time put an end to the ridiculous situation under which the *same* valve, according to the firm who sells it, is called a D.E.5, a DFA1, a B4, or a PV5D.E.

Supersonic or Stabilised?

Judging by the exhibits at the recent shows, and also by the components being much advertised at the present moment, it is expected that the supersonic set is to be the popular high-power set of the season. At the same time, one of our greatest wireless engineers has taken the opposite view, and specialised in a "straight" neutralised set. There is a good opportunity here for some of our readers to produce a critical review of the respective merits of the two types, assuming that equal skill and care is put into each.

It is, of course, obvious that an amplifier to work at a fixed wave-length of 3 000 or 6 000 metres is by far a more reasonable proposition than one to give equally good results of over a range of short waves from, say, 200 to 600. The question then is, whether the troubles and difficulties which may be introduced by the "frequency changer" necessary, do or do not outweigh the advantage.

Frankly, our own opinion is that these troubles are much overrated, and that the supersonic is undoubtedly superior for most purposes; but we should very much like to see a detailed discussion of the point from different individual points of view.

Amateur Research.

Mr. Ryan, in his notes on "Long Distance Work" in E.W. & W.E. for September last, made what we consider to be a very good point. He said, readers will remember, that now that amateurs have "DX'ed" half round the world, he proposed to devote less attention to simple distance records, but to note in particular any *use* made of such work in increasing our wireless knowledge.

The point is brought home by the account in our last issue of the Radio Research Board's tests on fading. Reading between the lines of the report, it is obvious that many of the amateurs who gaily undertook to make reports could not—or at any rate *did* not—send in regular full reports such as would have been of real scientific value when collated; and we feel that this is a serious reproach.

Wireless is beyond doubt a fine hobby, and has immense value in encouraging technical study; but we fear that much of the amateur work being done at the present day is just "hobby" work—like fretwork or stamp-collecting—and that some of those who claim to be scientific workers engaged on research have not yet learned the fundamental truth that *real* research demands previous knowledge, self-discipline, and above all incessant work, much of it most laborious and uninteresting; and is not quite the same thing as playing with a scientific novelty.

Readers must not imagine that we ignore the real work that is being done by some amateurs scattered all over the country. Fine work is being done; but one cannot deny the existence of the "fretworkers" as well; and some of them are vociferous on the ether.

The problems of transmission are extraordinarily difficult, and the expense of a real attempt to solve them is considerable. Might we suggest that there are still a few problems in reception, and that apparatus for serious work in this direction is by on means hard to acquire?

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The Rectification of Small Radio Frequency Potential Differences by means of Triode Valves.—Part I. [R134

By F. M. Colebrook, B.Sc., A.C.G.I., D.I.C.

IN a previous paper[1] the author has outlined a general theory of rectification and illustrated the theory by reference to typical crystal detectors. The present paper is the extension of the theory to valve rectification.

1. *General.*

There are three principal methods of rectification by means of triode valves. The first and most generally used is that commonly known as "cumulative grid rectification." This depends on the curvature of the grid-current—grid-voltage characteristic. For shortness, it will be referred to in this paper as "grid rectification." The second method depends on the curvature of the foot of the anode-current—grid-voltage characteristic, and will be referred to as "anode rectification." The third method is generally known as "autodyne" in relation to the reception of continuous waves, and is more suitably termed "homodyne" in relation to the reception of modulated continuous waves. These three types of rectification will now be considered separately, in sections A, B and C respectively. A fourth section, D, will be devoted to a general comparison of methods of rectification.

A.—Grid Rectification.

2. *Nomenclature.*

It will be shown in the course of the following discussion that the terms "cumulative grid rectification" and "grid-leak" are not accurately descriptive in relation to the great majority of practical applications of the above process at the present time. They are, in fact, a survival from the time when wireless telegraphy consisted exclusively of the transmission and reception of trains of damped waves, as applied to which process they were not inappropriate. In connection with the reception of unmodulated continuous waves the terms are definitely misleading, in that they bestow undue emphasis on a transient condition of secondary importance. Unfortunately this not very accurate nomenclature is probably too well established to permit of general acceptance of more suitable alternatives, but, as far as the present paper is concerned, the term "grid rectification"

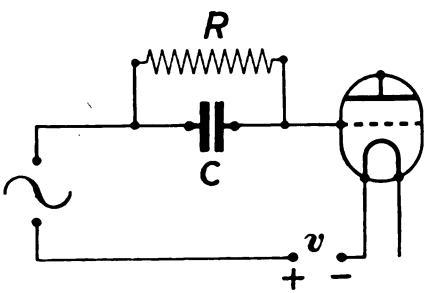

Fig. 1a.

will be used for the process as a whole, and "grid circuit resistance" for that element which is generally called the "grid-leak." The grid-circuit resistance must be distinguished from the internal resistance of the valve from grid to filament, which will be referred to as the "grid-filament resistance." This must be further distinguished from the resistance of the grid-filament path to current changes, which will be referred to as the "grid-filament slope resistance," since it is derived from the reciprocal of the slope of the grid-current—grid-voltage characteristic.

3. *The grid rectification circuit.*

The practical details of grid rectification are too well known to need description. Alternative arrangements are shown in

[1] "The Rectifying Detector." E.W. & W.E., March, April, May, 1925.

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Figs. 1*a* and 1*b*. Of these only the first will be considered in detail. The modifications of the analysis required for the second arrangement will not present any difficulty.

4. *The mechanism of grid rectification.*

It was shown in the paper referred to above that in a simple rectification circuit such as that illustrated in Fig. 2 the continuous current produced by the rectification of the alternating E.M.F. could be expressed in the form

$$i_c = \frac{E_c}{R + R_c} \quad \ldots \quad \ldots \quad (4.1)$$

where E_c is an effective continuous E.M.F. associated with an internal resistance R_c,

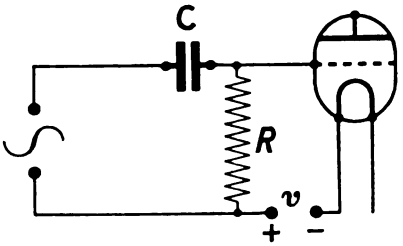

Fig. 1*b*.

acting in a circuit of external resistance R. In general E_c depends chiefly on the amplitude of the alternating E.M.F., but also to a less extent on R. The effective internal resistance R_c also depends to some extent on both the alternating E.M.F. and on R. The change of continuous potential difference across the resistance R is given by

$$v_c = \frac{R}{R_c + R} E_c \quad \ldots \quad (4.2)$$

If the terminal F of the detector be considered fixed in potential as regards direct currents, then v_c will be the change of potential of the terminal G. Thus the change of potential of G is a fraction $R/(R+R_c)$ of the total internal rectified E.M.F. E_c. Apparently this fraction can be made indefinitely near to unity by increasing R.

Now F can be considered to be the filament terminal of a grid rectifying valve, G being the grid terminal, and the rectifying grid-filament path taking the place of the detector shown in Fig. 2. The circuit then becomes identical with that shown in Fig. 1*a*. This simple derivation should make clear the functions of the different components of a grid rectifying circuit. That of the condenser is to provide a path of low impedance for the high-frequency currents flowing in the rectifying circuit. It was shown in the paper on the general theory of rectification that such a condenser materially increases the efficiency of the rectification process. The function of the grid circuit resistance is seen to be the externalisation, so to speak, of the internal rectified E.M.F., which, in the absence of this resistance, would remain internal, giving no change of mean grid potential. The function of the grid-filament path is the production of the rectified E.M.F. E_c.

The effect of the application of an alternating E.M.F. to the terminals of a grid rectifying circuit is thus seen to be a change of grid potential v_c. This will in turn produce a change of anode current given by

$$i = \frac{\mu v_c}{R_a + R_c} \quad \ldots \quad \ldots \quad (4.3)$$

where μ is the voltage factor of the valve, R_a the internal slope resistance of the valve from anode to filament, and R_c the external or load resistance in the anode circuit. This change of anode current is, of course, the real objective in the applications of grid rectification.

It has here been assumed that the changes concerned take place instantaneously. In practice this will not be strictly true, since a combination of a capacity and a high

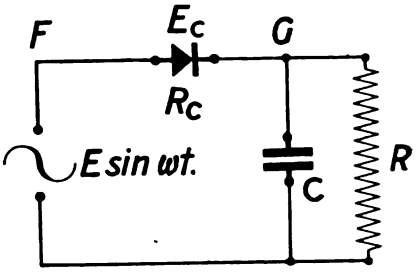

Fig. 2.

resistance is unable to respond instantaneously to a change of potential. At the instant of the application of the alternating E.M.F. there will therefore commence a building up process leading to the final potential change v_c. Also, when the signal ceases to act, there will be a gradual leaking away of the charge on the condenser, which will finally return to its initial equilibrium

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condition. Hence the terms "cumulative grid rectification" and "grid-leak." It will be shown, however, in the course of the detailed discussion, that the initial and final equilibria are the essential features of the process, the transient conditions being of very slight importance in the majority of practical applications.

Two points should be noted in connection with the above simple explanation. The first is that the actually utilised change of continuous current does not flow in the rectification circuit itself, but in an associated circuit. This is a point of difference from the cases considered in the paper on the general theory of rectification. The second is that as far as the rectification process itself is concerned, nothing is to be gained by short-circuiting the anode circuit load R_c with a condenser. It must be remembered, however, that if reaction effects are being utilised, then it will be desirable that there shall be appreciable high-frequency components of current in the anode circuit. In all such cases the use of a by-pass condenser across the anode circuit load will be advantageous.

In the detailed analysis of the process which follows the simplest possible case will first be considered, *i.e.*, the rectification of a pure sine wave high-frequency E.M.F. The other and more practically important applications of grid rectification will then be derived from this.

5. *Grid rectification in terms of a general form of characteristic.*

For any given conditions of anode voltage and filament current the relation between the grid current i and the grid voltage, *i.e.*, the difference of potential between the grid and the negative end of the filament, can be expressed in the form

$$i_g = f(v_g) \quad .. \quad .. \quad (5.1)$$

where f is some finite and continuous function. In general the characteristic does not pass through the origin, *i.e.*, i_g is not zero when v_g is zero. If the grid circuit is as shown in Fig. 1*a*, *i.e.*, it consists of a source of continuous potential v in series with a resistance R, then the initial value of the grid current will be given by

$$i_0 = f(v_g) = f(v - i_0 R) \quad .. \quad (5.2)$$

If now an alternative E.M.F.

$$e = E \sin \omega t \quad .. \quad .. \quad (5.3)$$

acts in series with v and R, there will be produced a change of grid current i of instantaneous magnitude given by

$$i_0 + i = f(v - i_0 R - i_c R + E \sin \omega t) \quad .. \quad (5.4)$$

where i_c is the mean value of i over a complete period T (*i.e.*, $T = 2\pi/\omega$). It is here assumed that the condenser connected across R is of sufficient magnitude to prevent any appreciable fall of high-frequency potential across R. Taking the mean value, over a period, of equation (5.4),

$$i_0 + i_c = \frac{1}{T}\int_0^T f(v - i_0 R - i_c R + E \sin \omega t)\,dt \quad (5.5)$$

or, putting $i_0 R = v_0$ and $i_c R = v_c$

$$v_0 + v_c = R\frac{1}{T}\int_0^T f(v - v_0 - v_c + E \sin \omega t)\,dt \quad (5.6)$$

In the general case, therefore, v_c is the solution of this equation.

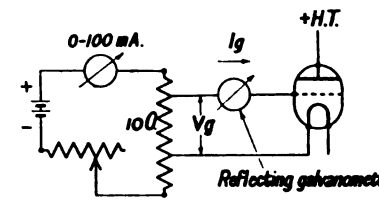

Fig. 3.

6. *The form of the characteristic for small receiving valves.*

The next step is clearly the determination of the at present unspecified characteristic

$$i_g = f(v_g) \quad .. \quad .. \quad (6.1)$$

and its expression in as simple a mathematical form as possible. A convenient circuit for the experimental measurement of the static characteristic is that shown in Fig. 3. The necessary grid voltages are obtained as the fall of potential due to a measured current in a known resistance, preferably of the four-terminal type. The grid currents are measured by means of a sensitive reflecting galvanometer. It will be found that the magnitude of the grid current is very sensitive to changes of filament voltage and anode voltage, which must accordingly be maintained constant at known suitable values.

A typical characteristic curve is that illustrated in Fig. 4, which refers to an Ediswan dull-emitter valve with an anode voltage of 50 and a filament voltage of 1.8.

It is now required to express the characteristic in mathematical form. A large

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number of forms of representation were tried without success, until it was discovered that the differential of the curve was very similar to the curve itself. As an example of the ease with which the obvious is overlooked the author confesses that he

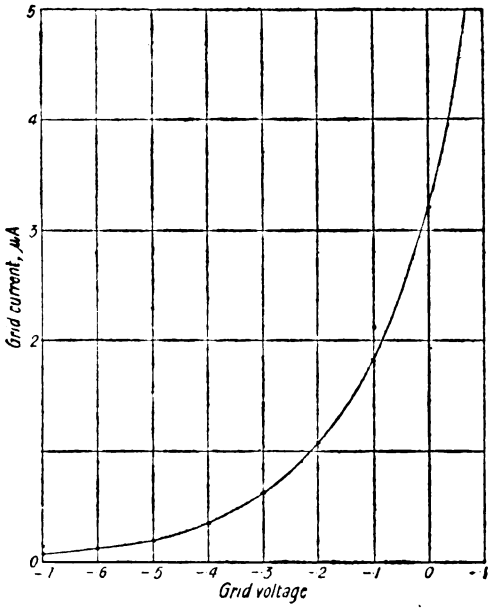

Fig. 4.

did not realise the significance of this fact until it was pointed out to him by a colleague (Mr. J. Hollingworth, of the National Physical Laboratory). It suggested, of course, an exponential form. This was tested by plotting the logarithm of the grid current against the grid voltage. The result for the curve of Fig. 4 is shown in Fig. 5. It is, to a close approximation, a straight line which can be expressed in the form

$$\log i_g = a' + b' v_g \quad .. \quad (6.2)$$

This is equivalent to

$$i_g = a\varepsilon^{bv_g} \quad .. \quad .. \quad (6.3)$$

where $\log a = a'$ .. .. (6.4)

and $b = 2{\cdot}303\, b'$

Both a and b can therefore be determined from the curve of Fig. 5.

A large number of small receiving valves were examined, and it was found that in every case a curve of the type $a\varepsilon^{bv_g}$ would represent to a fair degree of accuracy the variation of the grid current with the grid voltage. A number of the logarithmic lines are shown in Fig. 6, and the corresponding values of a and b are given in the following table.

Valve.	Anode Voltage.	Filament Voltage.	a	b
Ediswan R.	50	4	44.1×10^{-6}	4.01
Marconi R5V	50	5	10.35×10^{-6}	3.23
Ediswan A.R.	50	2	7.5×10^{-6}	5.12
Ediswan A.R.	25	1.8	5.83×10^{-6}	5.45
Marconi R.	50	4.5	2.06×10^{-6}	4.48
Marconi R.	50	4.0	$.29 \times 10^{-6}$	4.80
Marconi V24	50	5.2	2.43×10^{-6}	7.48

It will be noted that the constants differ very considerably in magnitude. It must be clearly understood that the exponential law is only followed over the ranges of grid voltage shown in the diagram. Generally

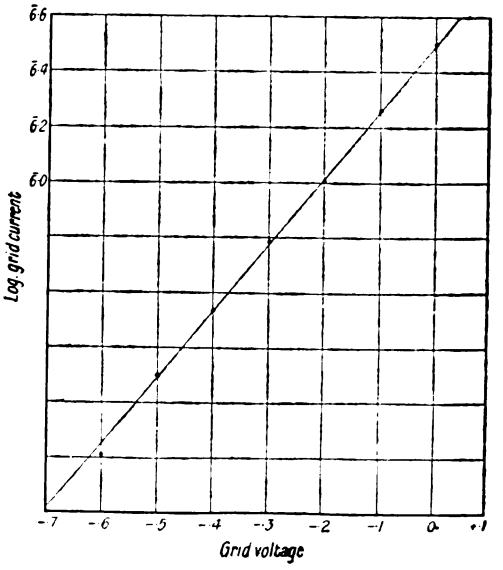

Fig. 5.

speaking it applies to all negative values, the characteristic becoming more nearly parabolic for positive values. In the great majority of practical cases, however, the valve will function inside the range of the exponential law.

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In Fig. 7 is given a series of logarithmic lines for an Ediswan dull-emitter valve for a constant filament voltage and various anode voltages. In Fig. 8 are shown the logarithmic lines for the same valve with a constant anode voltage of 50 and filament voltages of 1.8 and 2 volts.

The data so far obtained scarcely warrant a generalisation, but it appears that b, which is by far the more important factor, is principally a function of the geometry of the valve, while, for a given valve, a is chiefly a function of the conditions of operation, $\delta a/\delta v_f$ being positive and $\delta a/\delta v_a$ being negative.

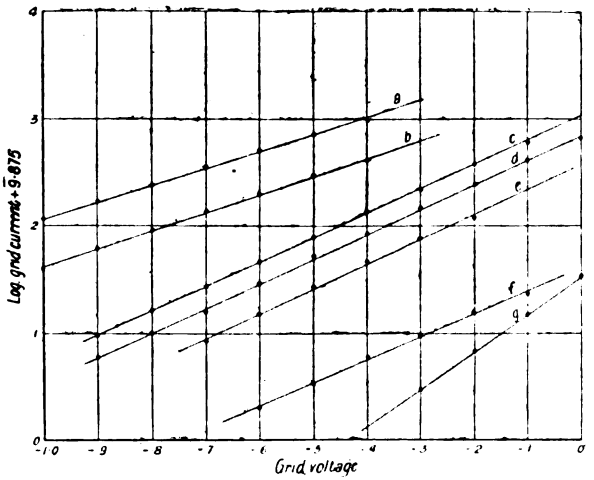

Fig. 6.

The matter is an important one from the point of view of design, and is worthy of a fuller investigation, which it is hoped will be possible at some future date.

7. *The solution of the rectification equation for an exponential characteristic.*

The discovery that the characteristic could be represented in the above simple form proved to be the key to the whole problem. Various other workers have investigated the matter with varying degrees of completeness (see, for instance, the excellent paper by E. B. Moullin, M.A., and L. B. Turner, M.A., published in the *Journal of the I.E.E.*, Vol. 60, pp. 706-719) but hitherto no general quantitative analysis has been presented, as the form of the characteristic was left unspecified. It is interesting to note, however, that the exponential form was distinctly foreshadowed in the above-mentioned paper.

In terms of the exponential characteristic, equation (5.2) becomes

$$i_0 = a\epsilon^{b(v-i_0R)} \quad (7.1)$$

$$= a\epsilon^{bv}\epsilon^{-bRi_0} \quad (7.2)$$

This equation cannot be solved directly, but the solution can be obtained in this way: multiplying each side by bR,

$$bRi_0 = abR\epsilon^{bv}\epsilon^{-bRi_0}$$

i.e., (7.3)

$$bv_0 = abR\epsilon^{bv}\epsilon^{-bv_0} \quad (7.4)$$

or

$$x\epsilon^x = y \quad .. \quad .. \quad (7.5)$$

where $bv_0 = x$ and $abR\epsilon^{bv} = y$.

Now equation (7.5) is a perfectly general one, containing no specific constants. The relation between x and y can be shown in the form of a curve, as in Fig. 9. For known values of a, b, R, and v, y is known and the corresponding value of x can be read off the curve. This gives bv_0, *i.e.*, v_0, and the initial equilibrium is determined.

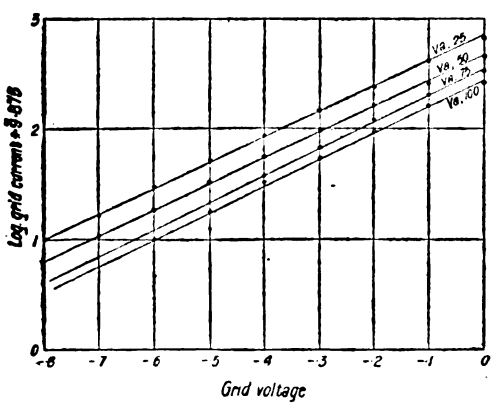

Fig. 7.

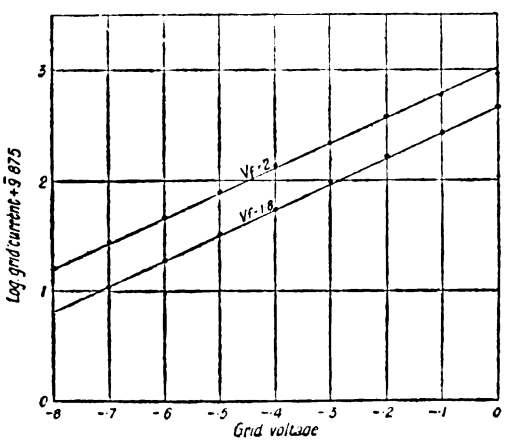

Fig. 8.

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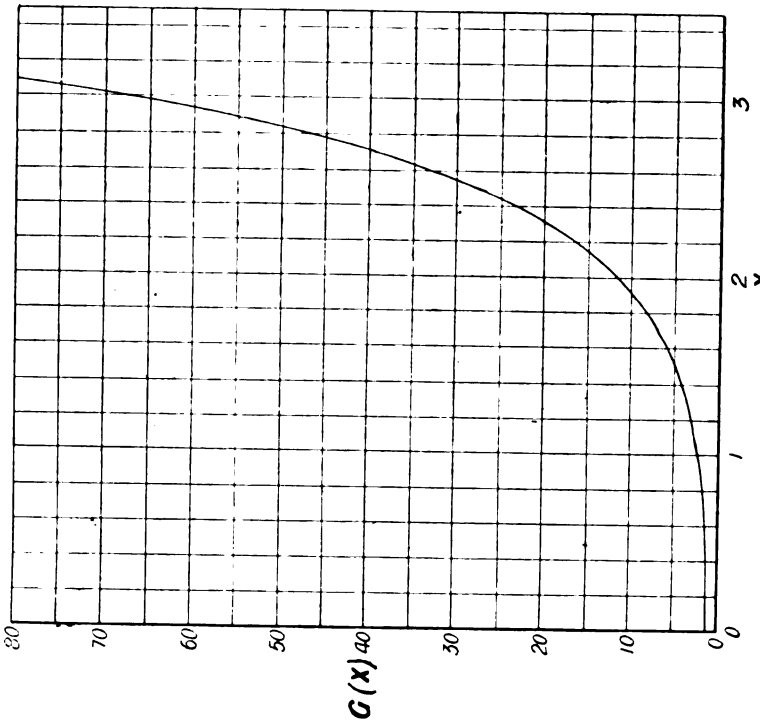

Fig. 10.

X	$G(X)$
0	1
.25	1.0634
.50	1.2660
.75	1.6466
1.00	2.2795
1.25	3.2882
1.50	4.8790
1.75	7.3690
2.00	11.2990
2.25	17.4800
2.50	27.2700
2.75	42.7600
3.00	67.5000

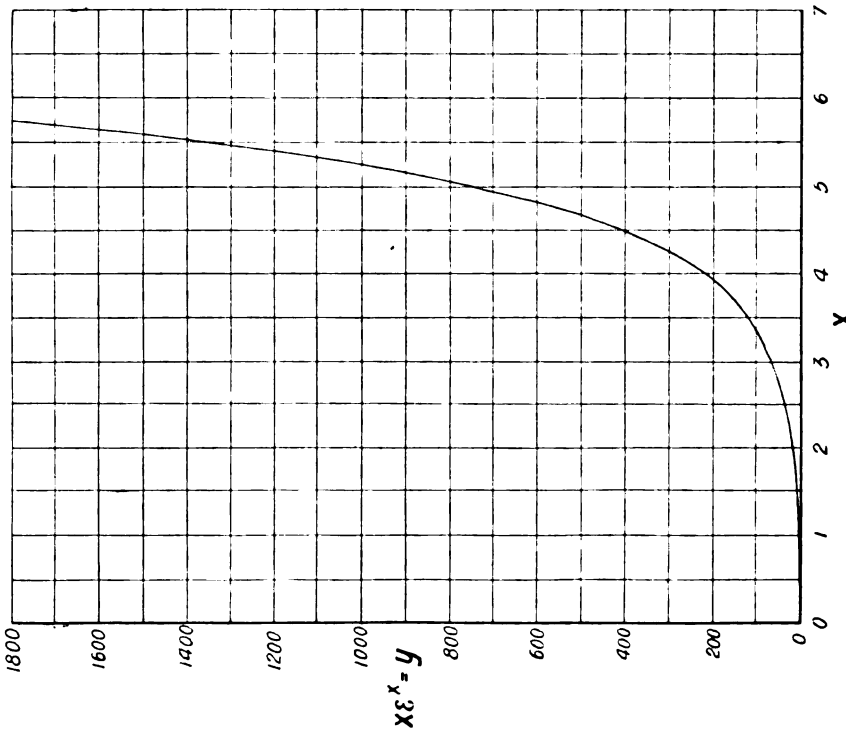

Fig. 9.

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Taking as an example

$$a = 3.16 \times 10^{-6}$$
$$b = 5.55$$
$$R = 1.89 \times 10^{6}$$
$$v = 0$$

then

$$abR\epsilon^{bv} = y = 33.1$$

From the curve

$$x = bv_0 = 2.56$$

Therefore

$$v_0 = .461$$
$$i_0 = .244 \times 10^{-6}$$

So much for the initial equilibrium. Considering now the effect of an applied signal voltage $e = E \sin\omega t$, equation (5.6) becomes

$$(v_0 + v_c)\epsilon^{b(v_0 + v_c)} = aR\epsilon^{bv}\frac{1}{T}\int_0^T \epsilon^{bE\sin\omega t}\,dt \quad (7.6)$$

i.e.,

$$b(v_0+v_c)\epsilon^{b(v_0 + v_c)} = abR\epsilon^{bv}\frac{1}{T}\int_0^T \epsilon^{bE\sin\omega t}\,dt \quad (7.7)$$

If now the right hand side of the equation can be determined this becomes another equation of the form $y = x\,\epsilon^x$ which can be solved in exactly the same manner as for the first equilibrium.

The evaluation of the right hand side is actually a simple and straightforward matter. It is given in detail in Appendix I. The result can be stated in the form

$$\frac{1}{T}\int_0^T \epsilon^{bE\sin\omega t}\,dt = G\left(\frac{bE}{2}\right) \quad .. \quad (7.8)$$

where

$$G(x) = 1 + x^2 + \frac{x^4}{2!^2} + \frac{x^6}{3!^2} + \frac{x^8}{4!^2}, \text{etc., } ad\,inf. \quad (7.9)$$

The integral can therefore be represented by a general curve, applicable to all cases of exponential rectification, by taking $bE/2$ as the argument. The curve is shown in Fig. 10 for values of x from 0 to 3, a range which will be sufficient for most practical purposes.

By means of the above two curves the change of mean grid potential corresponding to any given continuous wave signal amplitude can be calculated in a comparatively simple manner. For example, taking the values given above, and assuming a signal amplitude of .707 volt (*i.e.*, an R.M.S. value of .5)

$$G\left(\frac{bE}{2}\right) = G(1.964) = 10.5$$

Therefore

$$b(v_0+v_c)\,\epsilon^{b(v_0+v_c)} = 10.5 \times 33.1 = 348$$

and from the curve of Fig. 9

$$b(v_0 + v_c) = 4.38$$

and since, as already shown,

$$bv_0 = 2.56$$
$$bv_c = 1.82$$

and

$$v_c = .329 \text{ volts.}$$

From v_c the magnitude of the change of anode current can be calculated in the ordinary manner, which need not be described here.

If the change of anode current, or the change of mean grid potential, calculated in the above manner for a number of different signal amplitudes, is confirmed by actual measurement, then

(*a*) The above theory of the rectification process is correct ; and

(*b*) The dynamic characteristics of the valve are the same as the static characteristics ; or

(*c*) The deviations of (*a*) and (*b*) from the truth cancel each other.

Neglecting the remote possibility of (*c*), experimental confirmation of the analysis will establish the two very useful results (*a*) and (*b*).

8. *Experimental confirmation.*

The circuit shown in Fig. 11 was used for the experimental confirmation of the theory. The chief difficulty in measurements of this

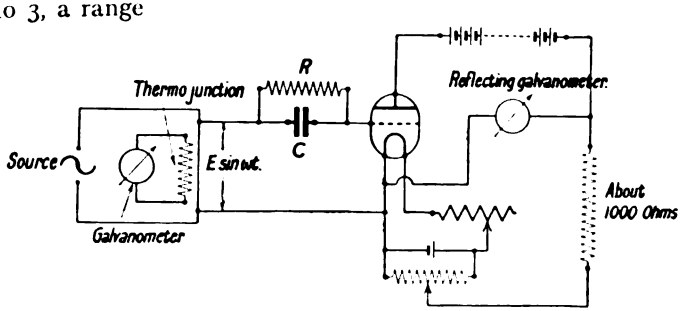

Fig. 11.

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kind is to obtain accurately known small voltages of the frequencies required. (The range covered in these experiments was from 75 to 750 kilocycles, *i.e.*, 4 000 to 400 metres in wave-length.) At very high frequencies the use of a contact thermo-junction is liable to introduce errors unless special precautions are taken. In the present case the necessary voltages were obtained as the fall of potential due to a measured current in a known resistance. To ensure that the current measured was actually flowing through the resistance the latter was used as the heater of a non-contact multi-junction arrangement. The changes of mean grid potential were determined from the consequent changes of anode current, the initial anode current being balanced out of the galvanometer circuit by means of the potentiometer arrangement shown in the figure. In order to relate the observed changes of anode current to the corresponding changes of mean grid-potential, the relevant portion of the anode current—grid

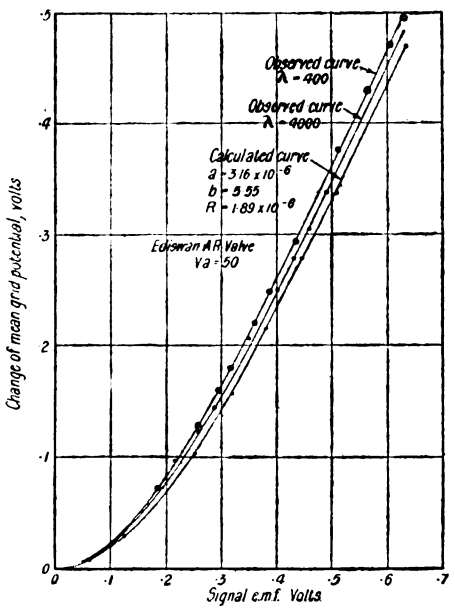

Fig. 12.

voltage characteristic of the valve was measured separately under the same experimental conditions of filament and anode voltage.

The valve used in these measurements was an Ediswan dull-emitter, its grid constants being

$$a = 3.16 \times 10^{-6}$$
$$b = 5.55$$

The anode voltage was kept constant at 50 volts, the filament voltage at 2 volts, and no additional grid potential was used (*i.e.*, $v = 0$). Two different grid circuit resistances were used, (*a*) 1.89×10^6 and (*b*) $.0878 \times 10^6$. Measurements were made at three frequencies, corresponding to wave-

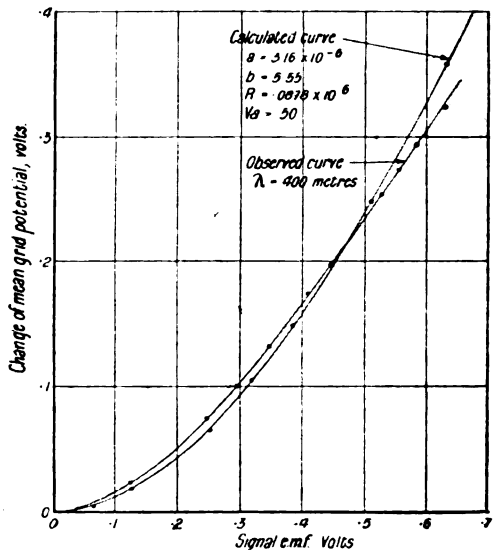

Fig. 13.

lengths of 400, 1 000 and 4 000 metres. In every case the variation with frequency was small, probably less than the limit of accuracy of the measurements.

In Fig. 12 the results are shown for the higher grid resistance, compared with the calculated curve determined from the measured grid constants in the manner described above. The comparison affords a very satisfactory confirmation of the theory, and shows that the characteristics of the valve determined at zero frequency appear to be identical with those corresponding to a frequency of nearly a million. There appears to be no appreciable time lag over this wide range of frequency.

In the curves of Fig. 13 are shown the results for the lower value of grid-circuit resistance. Here again the agreement is very good, though not quite so satisfactory from a theoretical point of view as in the former case, since the curves are not quite

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of the same shape. This is probably due to the fact that for this very low resistance the initial grid potential is only —.133 volt, which means that the operation of the valve will take the characteristic point into a region where the exponential law is not followed very closely. This is, in fact, an extreme case, so that the agreement is closer than might have been anticipated.

A further series of measurements was made with the anode voltage reduced to 25 volts, for which value the grid constants were found to be

$$a = 5.37 \times 10^{-6}$$
$$b = 5.6$$

It was found that there was apparently a considerable deviation of the measured from the theoretical curve. This is shown in Fig. 14. The reason for this deviation was soon discovered.

The method of determination of the change of mean grid potential involves the assumption that the anode current—grid voltage characteristic is a straight line over the range of the changes concerned. If it is not a straight line the high-frequency components of the anode current will themselves be partially rectified, giving a slight increase of anode current. The curvature of the anode current—grid voltage characteristic will thus give rise to a change of mean anode current opposed in direction to that given by pure grid rectification. Now with a low anode voltage the region of operation of the anode current-grid voltage characteristic will be rather near its lower bend and will therefore have a slight curvature.

This reasoning was confirmed by experiment in the above case. The grid circuit resistance was short-circuited and the galvanometer brought back to balance by applying an equivalent negative grid potential. The high-frequency potentials were then applied to the grid as before, and it was found that there was a small change of mean anode current in the reverse direction, as indicated above. The magnitudes of the changes corresponding to various applied voltages were measured and were added as corrections to the corresponding readings in the grid rectification measurements. The dotted line in Fig. 14 is the corrected curve obtained in this way. It gives a very satisfactory confirmation of the theory.

9. *The physical interpretation of the part played by the grid circuit resistance.*

It was stated in Section 4 that in all cases of rectification the fall of potential v across the load R in the rectifying circuit could be expressed in the simple form

$$v_c = \frac{R}{R_c + R} E_c \quad .. \quad .. \quad (9.1)$$

E_c being an effective rectified E.M.F. and R_c an effective internal resistance. It will be of interest to relate this to the case under consideration.

In the general case no simple expressions can be found for E_c and R_c in terms of the constants of the grid circuit, but certain approximations can be made if the signal amplitude is small, say, less than 100 millivolts, which enable the process to be interpreted very simply.

From equations (7.7) and (7.8),

$$b(v_0 + v_c)\varepsilon^{b(v_0+v_c)} = abR\varepsilon^{bv}G\left(\frac{bE}{2}\right) \quad .. \quad (9.2)$$

and since

$$bv_0\varepsilon^{bv_0} = abR\varepsilon^{bv} \quad .. \quad .. \quad (9.3)$$

$$(v_0 + v_c)\varepsilon^{bv_c} = v_0 G\left(\frac{bE}{2}\right) \quad .. \quad (9.4)$$

Now for small values of E, bv_c will also be small, and it will be permissible to simplify the above equation to

$$(1 + bv_c)(v_0 + v_c) = v_0 G\left(\frac{bE}{2}\right) \quad .. \quad (9.5)$$

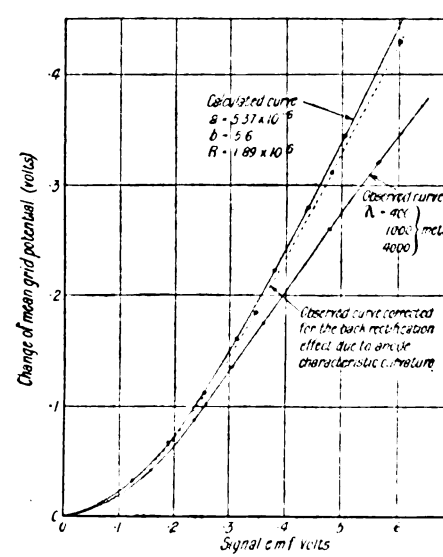

Fig. 14.

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and, neglecting bv_c^2,

$$v_0 + v_c + bv_0 v_c = v_0 G\left(\frac{bE}{2}\right) \quad .. \quad (9.6)$$

whence

$$v_c = \frac{bv_0}{1 + bv_0} \; \frac{G(bE/2) - 1}{b} \quad .. \quad (9.7)$$

$$= \frac{R}{R + 1/bi_0} \; \frac{G(bE/2) - 1}{b} \quad .. \quad (9.8)$$

Comparing this with equation (9.1) above, it is clear that the rectified E.M.F. E_c is given by

$$F_c = \frac{G(bE/2) - 1}{b} \quad .. \quad .. \quad (9.9)$$

$$= \frac{bE^2}{4} \text{ approx.} \quad .. \quad (9.10)$$

and the internal resistance R_c by

$$R_c = 1/bi_0 \quad .. \quad .. \quad (9.11)$$

It should be noted that R_c is actually the slope resistance of the grid-filament path at the initial point of operation, for, putting

$$i_g = a\varepsilon^{bv_g} \quad .. \quad .. \quad .. \quad (9.12)$$

$$di_g/dv_g = ab\varepsilon^{bv_g} \quad .. \quad .. \quad (9.13)$$

$$= bi_g \quad .. \quad .. \quad .. \quad (9.14)$$

Therefore

$$\text{slope resistance} = (dv_g/di_g)_0 \quad .. \quad (9.15)$$

$$= 1/bi_0 \quad .. \quad (9.16)$$

It was pointed out in Section 4 that the ratio of R to $R_c + R$ could apparently be made indefinitely near to unity by increasing R. This, however, is not the case in practice, since an increase in R will be accompanied by a decrease in i_0, *i.e.*, by increase in R_c. There is thus an upper limit beyond which an increase in R will not produce any appreciable increase in v_c. This point will be considered in fuller detail in a later paragraph.

10. *The high-frequency input resistance of the grid rectifying circuit.*

A full discussion of the input impedance of a rectifying valve would be a very lengthy business, since it should take account of the effect of inter-electrode capacity and inherent or externally induced reaction effects. This will not be attempted in the present section, the scope of which is limited to the discussion of the part of the input impedance which is due to grid-filament conductivity.

Equation (5.4) gave the instantaneous magnitude of the component i of grid current due to a given signal amplitude $e = E \sin \omega t$. The equation referred to the general characteristic. In relation to an exponential characteristic it becomes

$$i_0 + i = a\varepsilon^{b(v - v_c + E \sin \omega t)} \quad .. \quad (10.1)$$

$$= a\varepsilon^{b(v - v_c)} \, \varepsilon^{bE \sin \omega t} \quad .. \quad (10.2)$$

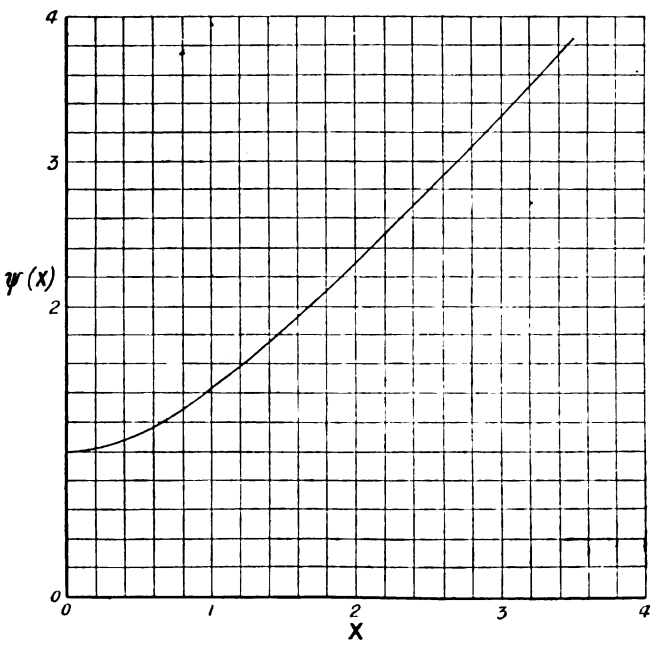

Fig. 15.

X	$\psi(X)$
0.0	1.000
0.5	1.120
1.0	1.430
1.5	1.853
2.0	1.315
2.5	1.835
3.0	3.300

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This component i will obviously consist of a continuous component i_c and a complete Fourier series of fundamental frequency $\omega/2\pi$. It can be shown[1] that the amplitude of the fundamental component is given by

$$I_1 = a\epsilon^{bv}\epsilon^{-b(v_0+v_c)}\, 2\phi\left(\frac{bE}{2}\right) \quad .. \quad (10.3)$$

where

$$\phi(x) = x + \frac{2x^3}{2!^2} + \frac{3x^5}{3!^2} + \frac{4x^7}{4!^2} \quad . . . \text{ etc., } ad\ inf. \quad (10.4)$$

Further, since

$$a\epsilon^{-b(v_0+v_c)} = \frac{i_0 + i_c}{G(bE/2)} \quad .. \quad (10.5)$$

(from equation (7.7)), equation (10.3) can be written

$$I_1 = 2(i_0+i_c)\frac{\phi(bE/2)}{G(bE/2)} \quad .. \quad (10.6)$$

Putting

Input high-frequency resistance $= R_1 = \dfrac{E}{I_1}$

then

$$R_1 = \frac{1}{i_0+i_c} \cdot \frac{E}{2} \cdot \frac{G(bE/2)}{\phi(bE/2)} \quad (10.7)$$

$$(10.8)$$

i.e.,

$$R_1 = \frac{1}{bi_0 + bi_c}\,\frac{(bE/2)\,G(bE/2)}{\phi(bE/2)} \quad (10.9)$$

The function

$$\psi(x) = \frac{xG(x)}{\phi(x)}$$

is shown plotted in Fig. 15. By means of this curve the variation of R_1 with E or with R can be very easily calculated. The curves of Fig. 16 illustrate the results for a valve having the grid constants

$$a = 3 \times 10^{-6}$$
$$b = 5$$

The chief points to be noted are:—

1. The effective high-frequency input resistance increases with the magnitude of the grid-circuit resistance (although the high-frequency currents do not flow through this resistance).

2. For a given grid-circuit resistance the effective high-frequency input resistance will decrease if i_0 is increased (*e.g.*, by applying an additional positive voltage v in the grid circuit). This point will be considered more fully later.

3. For small values of x, $\psi(x)$ does not differ very greatly from unity, which value it approaches as a limit when $x = 0$. The limiting value of the input resistance is therefore $1/bi_0$, which is otherwise obvious, since this is the slope of the grid voltage—grid current characteristic at the initial point of operation.

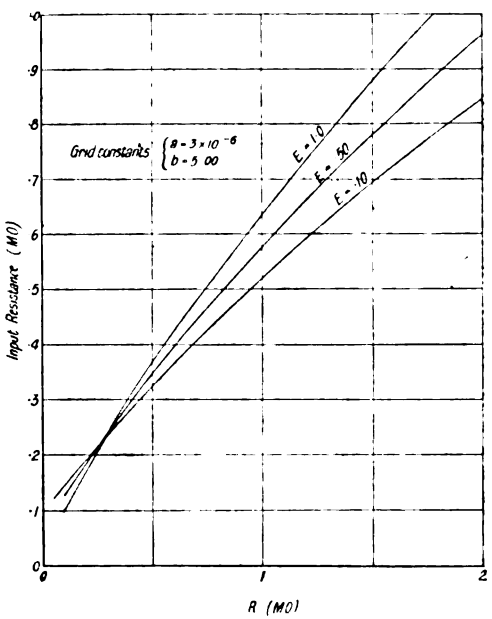

Fig. 16.

4. For a given grid-circuit resistance the input resistance increases with the signal amplitude, but the increase is relatively small.

11. *Independent control of the initial equilibrium, i.e., the effect of a grid potentiometer.*

From equation (7.2), the initial equilibrium is given by

$$i_0 = a\epsilon^{bv}\epsilon^{-bv_0} \quad .. \quad (11.1)$$

The initial grid potential v_g is

$$v_g = v - i_0R = v - v_0 \quad .. \quad (11.2)$$

[1] See Appendix II.

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By a simple transformation equation (11.1) can be put in the form

$$v = v_g + aR\epsilon^{bv_g} \quad .. \quad (11.3)$$

from which the values of v corresponding to known values of a, b, R, and v can easily be calculated. As an example the following table gives the results for a valve having the grid constants.

$$a = 3 \times 10^{-6}$$
$$b = 5$$
$$R = 10^6$$

v_g	v	R' Megohms.	$1/bi$ Megohms.
−.75	−.80	14.6	3.70
−.50	−.62	5.2	1.48
0	−.40	1.0	.495
.5	−.28	.36	.271
1.0	−.19	.20	.173
1.5	−.13	.10	.128
2.0	.08	.08	.100
2.5	.03	.02	.078
3.0	.00	.00	.066

The table also gives the values R', which is written for the magnitude of the grid-circuit resistance which would give the same initial grid potential in the absence of any additional applied continuous potential.

The above typical example will show the nature of the control of the initial equilibrium given by a grid potentiometer. It will be seen that a variation of the applied grid potential from .75 volt negative to plus 3 volts produces the same effect on the initial equilibrium as a variation of the grid-circuit resistance from 0 to 15 megohms. This does not mean that a grid potentiometer is in every way equivalent to what is generally known as a variable grid-leak, for it is only in respect of the initial equilibrium that they are similar in effect.

The effect of an additional applied continuous grid potential on the rectification performance of a valve is most easily seen in the equation for small signal amplitudes given in section 9, *i.e.*,

$$v_e = \frac{R}{R + 1/bi_0} \frac{G(bE/2) - 1}{b} \quad .. \quad (11.4)$$

The important thing to notice is that the second term on the right hand side, *i.e.*, the rectified E.M.F., depends only on b and the signal amplitude. The applied continuous grid voltage will therefore not affect this term at all. The remaining term, however, which determines what fraction of the rectified E.M.F. shall be available as a change of mean grid potential, will increase as i increases, *i.e.*, it will increase with an applied positive grid potential. It appears therefore that an applied positive grid potential does not increase the rectified E.M.F. but does increase that fraction of the rectified E.M.F. which is available as a change of mean grid potential.

Whether or no this will result in any increase in effective sensitivity in any given practical case will depend on the conditions of operation. It must be remembered that the above analysis has been based on the assumption of a constant input voltage. In practice the input voltage will depend to a greater or less extent on the damping imposed on the receiving circuit by the detector, and the increase of intrinsic sensitivity associated with an applied positive grid voltage will be accompanied by an increase of the damping effect of the detector. This is shown in the above table, which gives the values of $1/bi_0$, *i.e.*, the effective input resistance for small amplitudes, corresponding to various applied continuous grid voltages.

Further, it will be shown in a later section that the magnitude of the grid condenser must be such that its impedance at the frequency of operation is small compared with $1/bi_0$. A decrease in the latter will, therefore, call for an increase in the magnitude of the grid condenser, and this, for reasons to be given later, may be very disadvantageous.

In view of the above considerations, it is clearly impossible to generalise, but it seems likely that in most cases a small applied positive voltage will be advantageous, particularly if the increased damping so produced can be compensated for by reaction.

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APPENDIX I.

The evaluation of $\frac{1}{T}\int_0^T \epsilon^{bE \sin \omega t} \, . \, dt.$

$$\frac{1}{T}\int_0^T \sin^{2p} \omega t \, dt = \frac{1.3.5 \ldots . (2p-1)}{2.4.6 \ldots . 2p}$$

$$\epsilon^{bE \sin \omega t} = 1 + \sum_{n=1}^{n=\infty} \frac{(bE \sin \omega t)^n}{n!}$$

$$= 1 + \sum_{p=1}^{p=\infty} \left\{ \frac{(bE \sin \omega t)^{2p}}{(2p)!} + \frac{(bE \sin \omega t)^{2p-1}}{(2p-1)!} \right\}$$

Therefore

$$\frac{1}{T}\int_0^T \epsilon^{bE \sin \omega t} dt - 1 + \sum_{p=1}^{p=\infty} \frac{(bE)^{2p}}{(2p)!} \frac{1.3.5 \ldots (2p-1)}{2.4.6 \ldots 2p}$$

$$= 1 + \sum_{p=1}^{p=\infty} \frac{(bE)^{2p}}{(2)^{2p}} \frac{1}{p!^2}$$

$$= 1 + x^2 + \frac{x^4}{2!^2} + \frac{x^6}{3!^2} \ldots \text{etc., } ad\ inf.$$

where

$$x = \frac{bE}{2}$$

APPENDIX II.

The amplitude of the fundamental component of the high-frequency current in the grid-circuit is given by

$$I_1 = \frac{2a}{T}\int_0^T \epsilon^{b(v - v_0 - v_c)} \epsilon^{bE \sin \omega t} . \sin \omega t \, dt$$

$$\epsilon^{bE \sin \omega t} . \sin \omega t = \sin \omega t + \sum_{n=1}^{n=\infty} \frac{(bE)^n}{n!} \sin^{n+1} \omega t$$

$$= \sin wt + \sum_{p=1}^{p=\infty} \left\{ \frac{(bE)^{2p}}{(2p)!} \sin^{2p+1} \omega t + \frac{(be)^{2p-1}}{(2p-1)!} \sin^{2p} \omega t \right\}$$

Therefore

$$\frac{1}{T}\int_0^T \epsilon^{bE \sin \omega t} \sin \omega t \, dt = \sum_{p=1}^{p=\infty} \frac{(bE)^{2p-1}}{(2p-1)!} \frac{1.3.5 \ldots (2p-1)}{2.4.6 \ldots 2p}$$

$$= \sum_{p=1}^{p=\infty} \frac{(bE)^{2p-1}}{(2.4.6 \ldots 2p)^2} 2p$$

$$= \sum_{p=1}^{p=\infty} \left(\frac{bE}{2}\right)^{2p-1} \frac{p}{p!^2}$$

Therefore

$$I_1 = a\epsilon^{b(v - v_0 v_c -)} . 2 \left\{ x + \frac{2x^3}{2!^2} + \frac{3x^5}{3!^2} + \frac{4x^7}{5!^2} \ldots \text{etc., } ad\ inf. \right\}$$

where

$$x = \left(\frac{bE}{2}\right)$$

(To be continued.)

A Loud-Speaker Receiver on A.C. Mains.

By P. Johnson (G5IS). **[R343·7.**

Describing the principles and method employed to obtain both filament and anode current from the house mains.

LAST winter the writer carried out some experiments with a view to obtaining good loud-speaker signals from the local broadcasting station. Having 220V 50~ mains laid on at the house, these were used for the supply of L.T. and H.T. It was necessary that the apparatus should be cheap and reliable, and after many tests with thermionic rectifying valves, these were dropped, figuratively speaking. Firstly, valves suitable for the job are expensive; and secondly, filaments do not last for ever. A measure of success was attained by their use, but the greatest difficulty experienced was in getting perfect smoothing of the H.T. supply.

The Nodon cell was then pressed into service. Many experimenters regard the chemical rectifier as a messy arrangement which only rectifies on occasions and then only for short periods. Now the chemical cell, if made up with pure materials and a little care, is extremely cheap and reliable. In the case of the receiver to be described, the rectifier has been in use for five months and is still running without the slightest defect or cause for dissatisfaction. During this time it has had no attention whatever. The cells were constructed at a cost of about 9d. each, and four cells at a cost of 3s., or even eight at 6s. are cheaper than thermionic valves at 30s. each. Further, comparing performances, the writer prefers the chemical cells on account of the ease of smoothing the output.

Before giving a description of the receiver,

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the rectifying cells will be described. The containers are glass jars of a type generally used as receptacles for chemicals, and, like the rest of the material used in the cells, were purchased from Messrs. Griffin of Kingsway, London. The jars are $5\frac{3}{4}$ inches high, $2\frac{1}{2}$ inches square, and are fitted with flat corks $1\frac{1}{2}$ inches in diameter and $\frac{1}{2}$ inch deep. The aluminium electrode is of 2 mm. wire, the length of the submerged portion being $3\frac{1}{4}$ inches. The other electrode is a carbon rod 6 inches long and $\frac{1}{4}$ inch in diameter, such as is often used for optical lantern arcs. Connection is made to the carbon by taking three turns of tinned copper wire round the end of the rod, running a spot of solder between the turns, and while hot twisting the ends of the wire with pliers. On cooling and consequent contraction, the wire binds tightly on the carbon and good electrical contact is

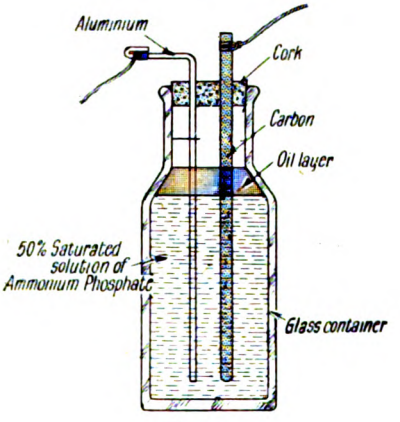

Fig. 1.

assured. In the case of the aluminium, the connection is made by wrapping several turns of the connecting wire about half an inch from the end of the aluminium and then nipping them by bending back the end of the aluminium with pliers. The electrodes are held in position by punching holes in the corks (see Fig. 1).

The electrolyte used is a solution of ammonium phosphate, and only chemically pure material should be used. The writer does not recommend the use of a saturated solution. Fifty per cent. saturation is sufficient, and the aluminium will keep quite clean and uncorroded for long periods.

Before putting the cells into use, it is most important that the aluminium electrodes be formed. Two rods should be placed in a jar of solution, and plugged across the mains with a lamp of the same voltage as that of the mains in series. The lamp will

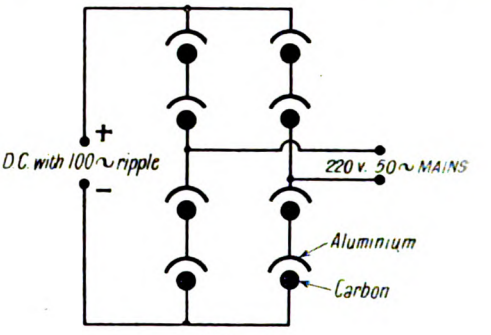

Fig. 2a.

light up fully for a moment and then slowly die out. When the lamp is extinguished, forming is complete, and if the operation is performed in a dark room, the electrodes will appear to be covered with a luminous sheen.

The glass jars should be filled up to the shoulder with fresh electrolyte and the carbons and aluminiums fitted into the corks. To complete the cells, a layer of light oil about half inch deep is floated on the electrolyte. Medicinal paraffin is excellent for this purpose, as it is without smell and of the right viscosity. The oil prevents creeping and evaporation of the electrolyte. To experimenters who have used electrolytic cells of this description, the cells may appear large when taking into consideration the small load. It must be remembered, however, that rectifiers must be kept cool, and with ample electrolyte, they are kept cool by convection.

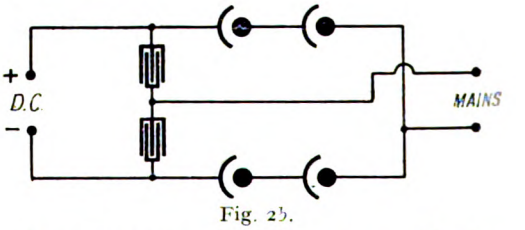

Fig. 2b.

Two systems of full-wave rectification may be used, and are shown diagrammatically in Figs. 2a and 2b. In Fig. 2b the condensers should be of large size, four μF or more, as they must be of low

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reactance at the supply frequency. It will be noticed that only four cells are necessary in this circuit, and as much as twice the voltage of the mains is available at the output terminals. On load, the voltage drops by an amount depending on the resistance of the cells and the size of the condensers used.

without the use of a normal earth, as the H.T. is earthed through the mains.

The H.T. smoothing circuit consists of a choke (which is the secondary of a burnt-out L.F. transformer in the writer's case) and a 2μF condenser. This will be found to eliminate all H.T. ripple.

The complete circuit, receiver, H.T.

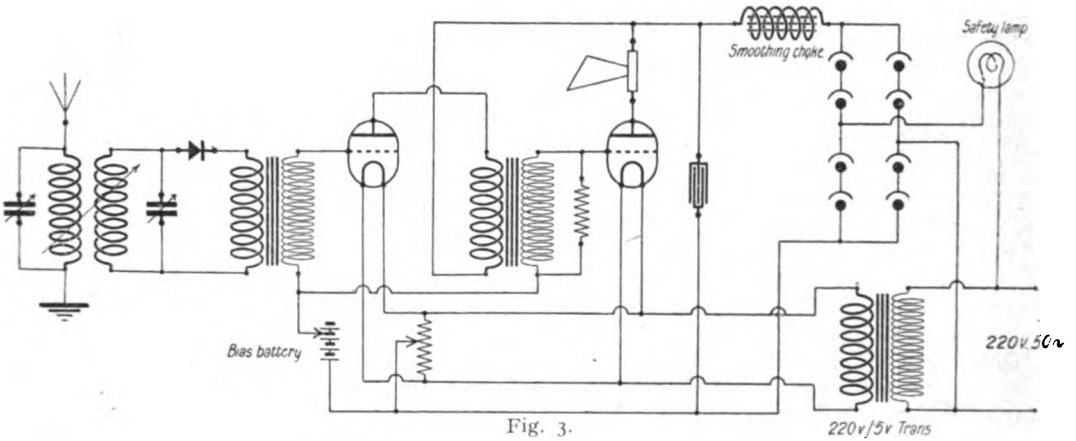

Fig. 3.

Using this circuit on the 220V, 50~ mains, two L.S.5 valves are comfortably supplied with 300V. For safety's sake, however, a lamp is included in the main's side of the rectifier, and so the voltage is reduced to about 200 on load. This is ample voltage for any British valve used in loud-speaker work.

With reference to the use of a carbon rod in place of the more usual lead electrode, it will be found that after several hours' use the carbon appears to dissolve to a slight extent. The electrolyte becomes discoloured, and after about 250 hours' working it appears quite inky. Whether the carbon does dissolve or whether the discolouration is caused by finely divided particles in suspension, the writer admits he does not know. Perhaps a chemist will explain. At any rate, there is no apparent loss of efficiency.

A tip for users of A.C. mains of 220V 50~ is the use of old Ford spark coils as transformers. The secondary winding is put across the mains, and about 3 volts A.C. is available from the other winding.

As one side of the mains is usually earthed, a loose-coupled circuit should be used; alternatively, a well insulated counterpoise earth. If the local station is within a few miles, good signal strength may be obtained

smoother, rectifier and L.T. supply is shown in Fig. 3.

Should it be desirable to use a valve detector in place of the crystal, it is most important that anode rectification should be used, and not cumulative grid rectification. Hum and distortion are certain to be

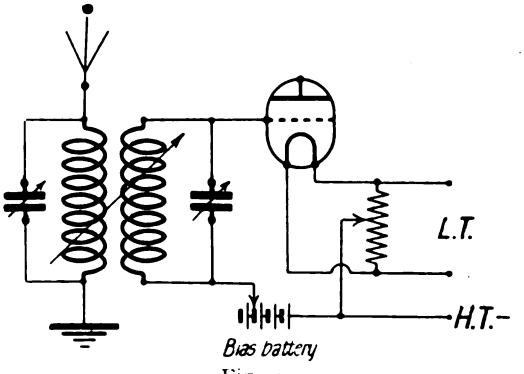

Fig. 4.

present if the latter method is used, and for fairly strong signals, anode rectification gives far superior quality. The connections for valve detection are given in Fig. 4.

In conclusion, the writer would be pleased to hear from anyone who finds this article of use, and would be glad to help in any cases of difficulty.

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Some Recent Research on Crystals.

By John P. McHutchison, M.A., B.Sc., and George T. MacLeod, B.Sc. (Hons.).

[R374.1

IT is a remarkable fact that the action of the crystal in a wireless receiver is still unexplained, and that no adequate theory of the changes occurring at a crystal rectifying-point has yet been advanced. On the basis of different physical or chemical ideas many suggestions have been made, but no satisfactory solution has so far been obtained, and the probability is that the final complete theory awaits the discovery of new facts.

The problem has been approached from many angles, and in the pages of the *Wireless World* has appeared the record of much pioneer work by Strachan. In the present article a new viewpoint is suggested, and a brief account is given of recent research on these lines.

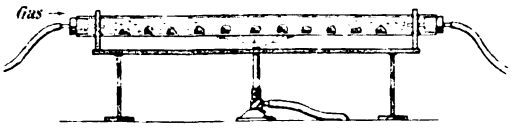

Fig. 1.

The starting point of the experiments to be described was that crystal action appears to be essentially a surface action, and that the interior of the crystal is not involved except as an ordinary metallic conductor. Rectification seems to depend upon a light contact between two conducting surfaces, and the action is believed to occur only in a very thin film, perhaps but a few molecules thick. Experimental facts are not lacking in support of this view, and perhaps the two most conclusive are amongst those that emerged in the course of some work conducted by one of us some time ago, and described elsewhere. These illuminating facts are :—

1. Rectification is obtained when the surface of *pure clean* mercury is *just* broken by a clean metallic point.
2. Two similar pieces of pure copper wire in light contact produced rectification.

Our object was, therefore, to investigate the nature of the surface of a rectifying crystal, and in particular to produce a good rectifying surface on galena, which generally does not rectify well in the natural state. Most of the proprietory brands of crystals appearing with pseudo-mineralogical names are of the galena type, and the majority of these are, no doubt, treated galena (lead sulphide).

Our first experiments were concerned with producing sensitive crystals from ordinary insensitive lumps of galena ore.

The Effect of Heat on the Surface of Galena Crystals.

Heating lead sulphide (PbS) in air, simply results in partial oxidation to lead sulphate ($PbSO_4$), which, since it is a non-conductor, cannot rectify. The heating had therefore to be done in a non-oxidising gas. The apparatus used is shown in Fig. 1.

Coal gas, which was the first to be tried, was passed slowly over pieces of crude galena contained in a combustion tube, heated by a spread flame, so that the different crystals were subjected to different temperatures, varying from 300°C to 800°C.

The heating was continued for four to five hours, and the crystals were cooled in a current of coal gas. The result of the treatment was very marked, in that crystals heated in the 800°C area were dull and tarnished, and on being tested were found to rectify splendidly (see below for methods of testing). When viewed through a microscope, the tarnished areas were seen to be covered with tiny cubic crystals of galena, whereas before treatment the surfaces were perfectly plane and clear. Several photomicrographs were taken with a Bausch and Lomb microscope and camera, using a 100 c.p. tungsten arc "Pointolite" for illumination.

Fig. 2 shows the surface of an ordinary insensitive piece of galena; Fig. 3 shows the same piece after treatment as described above, the small squares being really the faces of very tiny galena crystals, which had been formed by the heating.

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It appears therefore that the microscopic growth of cubic lead sulphide crystals had been formed on previously flat planes, and that the presence of these minute crystals was in some way responsible for rectification. It must be noted that the tiny crystals formed by this treatment were far too small to be apparent, as such, to the unaided eye, and were only detected by microscopic examination.

The results obtained suggested further heating of crude crystals of galena in other gases, all necessarily non-oxidising. The gases tried and the results obtained are shown in the following table.

this growth occurs is not exactly certain. It may be that the microscopic cubes are formed by sublimation and subsequent condensation, and indeed one treated specimen showed square markings on an otherwise plane surface.

The growth was most plentiful along cleavage lines, and was practically unobtainable on a polished surface, as is indicated by the photomicrographs (Figs. 4 and 5).

The action is certainly not a case of etching, for however produced, the cubes appear to be deposited on the crystal surfaces and stand out from it.

Chemical Formula.	Gas.	Remarks on Appearance of Treated Crystals.	Degree of Rectification.
I. —	Coal gas.	Surface tarnished.	*First class.*
H_2	Hydrogen.	Surface clear and sparkling.	
II. H_2S*	Sulphuretted hydrogen.	Very similar in appearance to hydrogen.	Fairly good, but definitely poorer than Group I.
SO_2	Sulphur dioxide.	The others in this group also similar, but less well-marked crystal growth.	
NH_3	Ammonia.		
CO_2	Carbon dioxide.		
N_2	Nitrogen.		
III. N_2O_4	Nitrogen peroxide.	Surface blackened with deposit of carbon owing to decomposition of gas.	Poor.
CH_4	Methane.		
C_2H_2	Acetylene.		
IV. Cl_2	Chlorine.	Surface attacked.	No rectification whatsoever.

* Heating in this gas was first suggested by Mr. W. Jamieson, B.Sc.Lond.

Interpretation of Results.

Galena rectification in its best degree would appear to be associated with the formation of *microscopic* crystals. How

Methods of Estimating the Degree of Rectification.

A simple receiver was employed with three crystal detectors, two containing

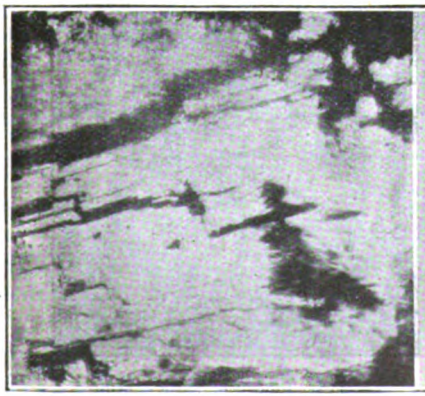

Fig. 2. *Natural galena.*

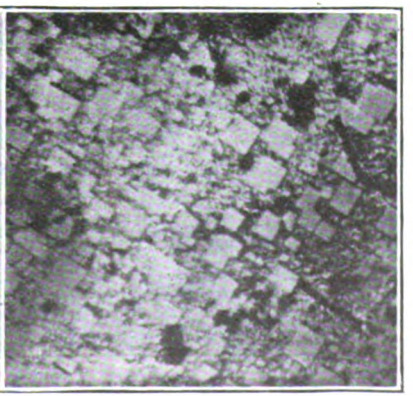

Fig. 3. *The same piece of galena after treatment in coal gas as described.*

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standard brands of crystals, the other being the treated specimen. It was thus possible to have immediate comparison of the laboratory crystals with market crystals. The methods employed for testing were :—

1. Personal estimate on 5SC's transmission.
2. Tuning out oscillations from a buzzer.
3. A directional method due to Fleming.
4. Comparative values obtained by shunting phones with a P.O. box, and putting in resistances till the phone signals were inaudible. The formula used was :—

$$S = \frac{R + r}{R} \text{ where}$$

S = degree of rectification (comparative).

R = resistance in P.O. box.

r = resistance of phones (generally 4 000O).

5. Deflection of galvanometer (D'Arsonval type).

Characteristic Curves for Treated Crystals.

These were determined in the usual way, and were noticeably different for the three grades of crystals produced as in Table above (see Fig. 6).

It will be noticed that the curve obtained for the poor crystal is very close to the straight line demanded by Ohm's Law for a non-rectifying point.

One or two other experiments, mostly negative in results, may perhaps be noted.

1. Treatment in Liquids.

A few tests were made to discover if boiling in hot liquids would cause the formation of a sensitive layer. For the most part no improvement in detecting qualities was noted, although boiling for five hours in

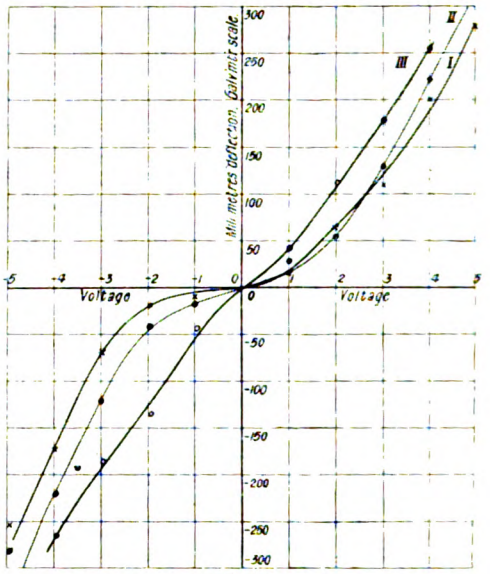

Fig. 6.

Characteristic Curves for the Crystals treated.
Curve I : Good rectifying crystal.
,, II : Second grade crystal.
,, III : Poor crystal.

NOTE.—*Each ordinate is the average of a number of readings for various test points taken on the surface of each crystal. The curves so obtained were indicative of the quality of the particular crystal, but were not sufficiently accurate to give precise degree of rectification.*

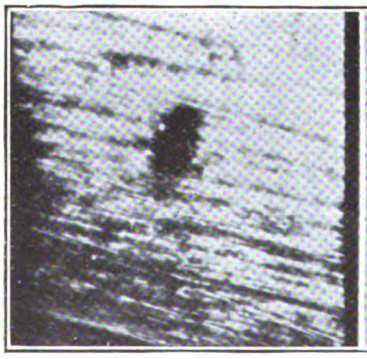

Fig. 4. *A piece of natural galena polished to a high degree of brilliance on a polishing lap.*

Fig. 5. *The same piece. Note that few cubes have been formed.*

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ammonium sulphide solution produced slightly sensitive crystals. No real results were perhaps to be expected from this method, since the temperature at which the deposition of the minute cubes occurred in the previous experiments was several hundred degrees higher.

2. Effect of Medium.

If, as appears most likely, rectification is solely a surface phenomemon, it would be quite feasible that a change in the medium surrounding the detecting point might make some alteration in the action. It was considered that if some gas other than air were employed, a poor crystal might be improved, and a good crystal made better. A Burndept detector was used, and two side tubes sealed on the glass cylinder for the admission of the gas, and numerous tests were made, but no change of any kind was noted.

When the detecting point was immersed in a *liquid*, no alteration took place unless the liquid was an electrolyte, when rectification was completely destroyed. Non-electrolytes, such as chloroform, alcohol, or carbon tetrachloride produced no effect at all.

Still relying on the surface nature of detection, two other series of tests were made :—

1. Various kinds of crystals were sealed into a tube with radon (*i.e.* radium emanation) and an active deposit of great electronic emitting power was thus formed on the surface of the crystals. The result was that the rectifying power was removed, since as in the case of the electrolytic medium ordinary electric conduction formed an easier path than the high resistance of the crystal point.

2. A very good galena rectifier was made most simply by precipitating lead sulphide from a solution of a lead salt with sulphuretted hydrogen gas. The precipitate was thoroughly washed, dried in a water oven, and then compressed tightly in a tabloid press. The sides of the galena sticks thus produced, polished in the process of compression by rubbing on the walls of the tabloid press, were found to have excellent rectifying surfaces.

A Short Wave Tuner.

THE "Bruno" 99 Tuner, which is being marketed by the Wholesale Wireless Co., of 103, Farringdon Road, London, E.C.1, has just been tested by us, with very good results.

The tuner is designed for short wave work, from about 20 to 100 metres, and comprises three specially wound coils, an aerial coil, with fixed coupling to a secondary coil, and a reaction coil, which is rotatable within the secondary.

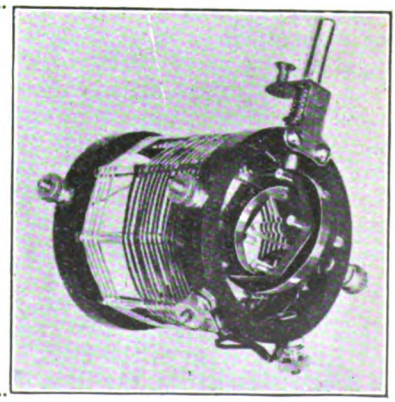
The former on which the aerial and secondary coils are wound is made of a number of quartzite rods supported by two rings of ebonite, on which the various terminals are fixed.

The aerial and secondary coils themselves are wound with strip metal about 1/16 in. wide, the metal being copper or phosphor-bronze in the case of the secondary coil and what appears to be aluminium in the case of the aerial coil. The numbers of turns in these coils are respectively 12 and 4, the reaction coil having 15 turns. This coil is fitted with a ¼ in. spindle, to which a knob can be attached. The aerial coil is untuned, and is spaced about ½ in. from the secondary.

We confined our tests to the secondary coil alone, and found that the inductance was 10.9μH the H.F. resistance was 0.9 ohm, the self-capacity 2.5$\mu\mu$F and the power factor .004 8. As would be expected from the design of the tuner, these results are very good, the power factor being particularly low.

To get an idea of the tuning range, we calculated the minimum and maximum wave-lengths which would be obtainable with a .000 25μF variable condenser.

The minimum wave-length is, of course, largely dependent upon the minimum capacity of the condenser and the capacity between connecting leads. Taking this total minimum capacity to be 20$\mu\mu$F, the minimum wave-length of the tuner will be about 27 metres and the maximum about 102 metres.



The short-wave tuner described herewith. It should be useful for DX reception work.

Owing to the constructional difficulties of a component such as this, the price is necessarily higher than usual, being 36s. Those, however who are interested in short wave work (and there will be many during the coming winter), will not object to this, providing the tuner is really good, as is this one.

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Autumn Presidential Address to the Radio Society

23rd September, 1925, on

The Mechanism of Radiation.

By Sir Oliver Lodge. **[R110·6**

WHATEVER radiation may be it is certainly an affair of the ether: it is the way in which the ether transmits energy. Thus and thus only is energy transmitted across empty space, that is across space empty of matter. There are reasons for asserting that no piece of matter is in contact with any other piece, and that between every atom, or the constituents of every atom, empty space exists, that is to say every part of space is filled with ether. And the connection between one piece of matter and another—the connection between world and world, and the connection between atom and atom—is maintained by radiation.

Radiation travels at one definite velocity, which must depend on the medium through which it moves, that is on the properties of the ether. Hence to understand the mechanism of radiation we ought to understand the constitution of the ether.

But we don't.

There have been attempts to regard the ether as an elastic solid; or alternatively as an extremely viscous liquid like pitch, rigid to rapid forces, permeable to slow ones. The only justification was that such a solid would transmit transverse waves, whereas no simple fluid can transmit any but longitudinal waves. Lord Kelvin expended much ingenuity on elastic solid theories of the ether, but in the end had to confess failure. No mechanical theory of radiation works.

Clerk Maxwell's electro-magnetic theory does work. Certainly the radiation is due to a combination of the ether's electric and magnetic properties, the lines of force being at right angles to each other and in the same phase, with the direction of propagation at right angles to both.

But an electro-magnetic explanation is not ultimate. We want to know more about what electricity is and what magnetism is. There have been attempts to explain the magnetic field in terms of spin; and indeed many of the magnetic properties of atoms suggest gyrostats. So that there have been attempts to explain the transmission of transverse waves of a fluid in terms of vortex motion. The elasticity necessary can be imitated by an arrangement of gyroscopes. Lord Kelvin initiated a theory of kinetic elasticity, in which springs could be imitated by rigid bodies in spinning motion. And FitzGerald tried to work out a theory of the ether in terms of what he called a "vortex sponge."

These elaborate and difficult mathematical attempts are imperfect at present: there are difficulties about stability. But the last word has not been said about them: they may turn out to be steps in the right direction. The effort should not be abandoned until all the possibilities associated with the hydrodynamics of a perfect fluid are exhausted. Vortex theory is a complicated branch of mathematics; indeed it is not so very long since it was begun, by Helmholtz.

If this hydrodynamic could be developed and fully worked out, it is probable that the whole of Physics would be covered; moreover a complete treatment of Physics would include Chemistry, and in fact would constitute an explanation of the material universe, except in so far as Life and Mind may modify it. But notice that even a complete theory of the purely material universe would not allow for free will or planning for the future; everything would be controlled and dependent on the present and the past; and inasmuch as this is contrary to experience, we perceive that the material universe is not the complete universe, that the universe as a whole contains a great deal else. Nevertheless from the point of view of the physicist he may reasonably strive to reduce his aspect of it to ether in various states of vortex motion.

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For what we know primarily through our senses is matter. It is that of which our bodies, and therefore our sense organs, are composed; and it may be said that they tell us of nothing else. (Even matter is an inference from our senses of force and motion. But let that pass. Most things are really inferences; for without intelligent appreciation and interpretation our information would be very small.)

Meanwhile it is interesting to see what position the intuition of Faraday led him to take about the nature of radiation, nearly a century ago.

He (Faraday) begins one of his papers with the following passage:—

Extract taken from Supplement to NATURE, *27th June*, 1925.

"That wonderful production of the human mind, the undulatory theory of light, with the phenomena for which it strives to account, seems to me, who am only an experimentalist, to stand midway between what we may conceive to be the coarser mechanical actions of matter, with their explanatory philosophy, and that other branch which includes or should include, the physical idea of forces acting at a distance.

"And admitting for the time the existence of the ether, I have often struggled to perceive how far that medium might account for or mingle with such actions generally, and to what extent experimental trials might be devised, which, with their results and consequences, might contradict, confirm, enlarge, or modify the ideas we form of it, always with the hope that the corrected on instructed idea would approach more and more to the truth of nature, and in the fullness of time coincide with it."

We have now in this century analysed matter into electrons and protons, that is into electric charges. Electricity and magnetism are affairs of the ether, hence matter is resolved into modifications of ether, just as much as radiation is. What kind of etherial motion constitutes an electron we do not yet know, but that is not our present business. We want to know what kind of motion constitutes radiation, and even that we cannot answer fully. We have to explain radiation in terms of the known and comparatively familiar phenomena of electricity and magnetism. This was begun by Clark Maxwell and continued by Hertz.

In the 'seventies and 'eighties of last century there were many of us contemplating Maxwell's waves and trying to produce them. I partially succeeded, but Hertz went one better, displaying them in a wonderful manner and also giving their theory in some detail, based upon Maxwell's more general theory, but worked out by Hertz with consummate skill. The mechanism of Hertz radiation, that is of the ether waves we use in wireless telegraphy, can be represented diagrammatically in a well-known way in terms of lines of force.

Referring to Hertz's diagram of the lines of force caused by electric charges surging up and down an aerial or dumb-bell radiator, it is well known that the lines cross or intersect at one point (about a quarter wave-length distant from the origin), and that beyond that point a loop is thrown off. The energy nearer the crossing-point returns to the conductor; the energy beyond that crossing-point advances out into space as independent wave motion. A certain amount of energy is shocked off at every oscillation, in accordance with diagrams illustrating the lines of force in different phases.

The question arises whether these lines of force are physical realities or only geometrical abstractions. Most of us thought they were abstractions. Faraday seems sometimes to have had an instinct that they might be real: and that great master in Physics, Sir J. J. Thomson, has always had a suspicion that they were real, and has treated them accordingly; and now the discovery by Max Planck of the quantum seems to me to justify that suspicion, and in a sense to confirm or corroborate some of the speculations of Sir J. J. Thomson, which hitherto perhaps have been looked at rather askance.

To understand what I mean by this, let us return to the Hertz diagram for the emission of radio waves. If the lines of force are realities, the loops which are thrown off by a transmitting aerial are not mere pictorial representations or diagrammatical illustrations but are a bundle of physical realities, each loop with an independent existence, *each loop constituting a quantum.*

Hitherto it has been thought that the idea of the quantum only applies to ultra-microscopic Physics, that it is not met with until we come to atomic dimensions, that it has to do with the discontinuities of atomic matter, and that for large-scale phenomena the quantum need not be considered. Certainly in engineering practice the quantum need not be considered, for it has no practical bearing on large-scale

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phenomena. Nevertheless I think it exists, though of so feeble an intensity that myriads are required to achieve any result, and that accordingly the individual quantum can be ignored. I conceive therefore that what we detect in radiation emitted by atoms is also occurring in radiation emitted by antennæ. But here I think I am in conflict with the views of Sir J. J. Thomson as so far expressed: at any rate he is not responsible for what I say on this part of the subject, and he may disagree with it; in which case it is likely to be wrong. But I put it out for what it is worth, in order that it may be criticised. What I suggest is that *the quantum arises from the reality of lines of force.*

I have said that a Hertz radiator emits quanta. And it is quite easy to calculate their energy for radiation of any given wave-length. Their energy is simply inversely as the wave-length.

The expression is $hc\,\lambda$; that is, if the energy is measured in ergs, and the wave-length in centimetres.

The energy in ergs is $\frac{18 \times 10^{-17}}{\lambda}$

For instance, if $\lambda = 180$ centimetres an energy quantum is the trillionth of an erg. So you see it is fearfully small for radio waves; but it is a good deal bigger for short waves than for long ones. The number of quanta emitted in a single swing of an aerial must be enormous; it will depend on the number of its lines of force, and that must at least be as numerous as the electrons in the terminal charge. Knowing the terminal charges, we can reckon the number of electrons. We can thus see how many lines of force go to a single electron. We can also reckon it in terms of energy; but I am not going to trouble you with arithmetic. Suffice it to say that the kind of quanta emitted by an aerial are individually very large and very feeble: so that to absorb them something nearly as large as that which emitted them, that is some kind of aerial, is required. They are not likely to have any effect on atoms and their attached electrons.

Have they then no effect on loose electrons? Can they not make an electron jump at all? Yes, they can, and we can reckon how much they will make an electron jump, that is what speed they can impart to it. Being big, they will encounter a great many, but, being weak, they won't make them jump much.

Absorption of radiation only occurs when an atomic electron is made to jump out of one orbit into another, or it may be out of its orbit into free space. To do that requires quite a lot of energy. A quantum has to be energetic to do that. But there would be no absorption if it was not done, and accordingly these long waves are not absorbed by any crowd of electrons they may encounter. Short waves are absorbed in a curious metrical and definite manner, in accordance with the theories of Bohr, thereby giving a definite absorption spectrum. But that again is not our present business.

That the long waves actually do disturb free electrons a little, is required by the theories of long-distance transmission, and the Heaviside layer, and all those ideas so well elaborated of late by Eccles and Larmor. And it is easy enough to reckon how much the quantum of radiation of any wave-length will make an electron jump. For the equation is:—

$$\frac{hc}{\lambda} = \tfrac{1}{2}\, mv^2$$

And since h and m are of the same numerical order of magnitude in the c.g.s. system, we may say that on that system of units the order of magnitude of the velocity imparted to an electron is $\sqrt{\frac{c}{\lambda}}$.

Or more closely $\sqrt{\frac{13c}{\lambda}}$ centims per sec.

For a wave 40 metres long this amounts to 100 metres a second (which for an electron is exceedingly slow), about 200 miles an hour, that is of the order of magnitude of some motor cars and aeroplanes.

The voltage required to give such a speed as that to an electron is next to nothing. ($V = 3 \times 10^{-16} u^2$) about the thirty millionth of a volt.

Nevertheless though the waves have but little effect on the electrons, loose electrons, ionised by other means, have some effect on the waves; and it appears to be owing to that effect that some of these long waves are able to curl round the earth without absorption and reach the Antipodes.

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Atomic Radiation.

Now let us contemplate atomic radiation, which, as many of us know, is on Bohr's theory due to the drop of an atomic electron from one orbit to another; or a drop from space into one of the atomic orbits. Many have been the attempts to explain how such a drop can emit radiation. I have tried to think of the nucleus of the atom as surrounded by a series of elastic films, due to some ether vortex motion, which catch and retain the electron, and quiver with the impact. But it does not seem to work, and I don't think I have ever published the attempt. It seemed to have promising features, but they tended to evaporate on further scrutiny; and whenever that happens one may suspect that one is off the track of truth.

A much better attempt has been made, quite recently, by Sir J. J. Thomson, in the *Phil. Mag.* for October last year, and has been used by him as a theme for popular exposition in his Fison Memorial Lecture at Guy's Hospital on the 7th May this year, with Lord Balfour in the Chair, a Lecture which has just been issued by the Cambridge University Press under the title *The Structure of Light.*

For, mark you, the structure of light has been under debate through about half the years of the present century, that is for about a decade. Some of you have heard Professor Lorentz lecture brilliantly on the subject at the Royal Institution. The theory of quanta and the undulatory theory of light were in the field against each other. They each explained one set of phenomena and declined to explain the other. When the action of light on atoms and electrons was under consideration, the quantum theory was supreme, and the wave theory hopelessly out of it. When the long-known phenomena of Optics were being treated, the quantum failed utterly, and the wave theory was entirely satisfactory, enabling new results to be predicted, as well as accounting for the old. Each was supreme in its own domain, and hopeless in the other. The conflict was likened to a fight between a tiger and a shark: they never really came to grips. But everyone had a sort of feeling as if somehow they must both be true, and Sir J. J. Thomson has made a valiant attempt to reconcile them.

Present extended knowledge seems to revive the old theory between the corpuscular and the wave theory; and it has been found that Sir Isaac Newton, though the founder of the corpuscular theory of light, perceived that a wave theory was necessary too, that is, his corpuscles had to be affected with a periodicity in space and time, which might be likened to a frequency or a wave-length. And unless this semi wave-idea was introduced, certain optical phenomena (diffraction, interference, and the like) refused to be explained.

Sir J. J. Thomson's is an attempt to reconcile the corpuscular and wave theories; or at least it may be so expressed, but we must be cautious in our terms. A corpuscle is a thing travelling through the ether at its own speed, depending on the velocity of projection. There is no such phenomenon as that in light. The thing that travels can only be an affection of the ether, for it travels at the one etherial velocity. Sir J. J. Thomson's corpuscles are not real corpuscles, though he seems rather to call them corpuscles and to say that they excite waves which travel at the same speed. I would rather say that they were themselves of the nature of waves in some respects, though apparently vortex rings, but vortex rings with a wave-length equal to their circumference.

My attempt or suggestion is after all only a modification of his, and depends like his on treating the lines of force as realities; but it would seek to explain light in terms of radio or Hertzian waves, that is to say to explain it on the same lines. The effect of a sudden drop of an electron from orbit to orbit is to bend the lines of force and form and liberate a loop, which shall travel out into space as a quantum of energy, a free ether disturbance which can only exist by travelling with the speed of light; but, as far as I can see, travelling edgeways, not broadside on. It is itself a purely etherial disturbance with all the requisite periodicity. It is in fact just like the disturbances we receive on our aerials; it has a definite wave-length, and it requires no supplementary generation of waves for its motion. It is itself a wave, and yet it is itself a projectile.

As emitted by an atom it is exceedingly minute, it may penetrate a great number of electrons without hitting any, but if it does hit any it will give up its energy and make

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that electron jump. It will make it jump not a little; it may jump enough to get clear out of an atom if the wave-length is sufficiently short, as it is in the case of X-rays. The velocity imparted to an electron by an X-ray wave of length 10^{-8} cm. will be 10^{8} cm. per sec.—1 000 kilometres—which corresponds to 3 volts. Even if the wave-length is rather longer, like that of visible light, it can still make it jump from one orbit to another, and can thereby deliver up its energy to the atom, and thus be absorbed. If it cannot do that, if when it jerks an electron up the speed is not sufficient to carry it to the next stable orbit, the electrons will drop back again and emit a precisely corresponding pulse; so that the radiation will not be absorbed, but will go on just as if nothing had happened, except indeed that it has been retarded a little by the absorption and re-emission. This delay might be supposed to account for the lessening of velocity as waves of light go through a transparent substance. I am afraid it won't work like that however, at any rate I haven't thought about it enough. If the electron is jerked up through several orbits and then drops back to an intermediate one we shall have fluorescence; if the drop back is delayed for some little time (it may be only the fraction of a second or it might be some minutes) we shall have phosphorescence.

But all these things are off our immediate beat. What I want to call your attention to is Sir J. J. Thomson's theory, whether in its original or in a modified form, and especially to call attention to the probable fact, which at present I think has been overlooked, that the same sort of phenomenon which emits Hertz waves on a large scale may emit light and X-rays on an atomic scale, and that the quantum is as real in one as in the other; except that the *atomic* loops are extremely energetic and have a great effect on the atoms over which they pass, giving us the phenomena of photo-electricity, and incidentally (as I think) giving us vision, photographic action, and the photo-synthesis of chemical compounds, especially of starch and sugar in the leaves of trees.

Furthermore we are beginning to learn what radiation can accomplish in the interior of stars. One of the most amazing and interesting discoveries of recent times is the discovery by Eddington of the dissociated gaseous nature of all stars, even those of great density, and the discovery that it is possible to have ionised gas in a condition 50 000 times as dense as water, at the lowest estimate—it may be more than that—proving how absolutely it is true that the ultimate particles of which matter is composed do not come into contact, but can be squeezed nearer and nearer together by forces unknown.

Thus it happens that the companion of Sirius, barely visible even in a large telescope, and yet extremely massive and therefore very bright, is visible so dimly only because it is so small; almost as if something like the sun were compressed until it was no bigger than something like the earth or one of the other planets, say the planet Uranus.

Thus the sciences of Astronomy, Chemistry, and ultimately all other non-mental sciences, will be linked up together, mainly by the phenomena of radiation—that is, by the remarkably comprehensive properties of the Ether of Space.

* * *

At the conclusion of the meeting a vote of thanks was proposed by Admiral Sir Henry Jackson, G.C.B., K.C.V.O., and was seconded by Mr. A. A. Campbell Swinton, F.R.S.

The next meeting will be held on Wednesday, 25th November, 1925, at the Institute of Electrical Engineers, commencing at 6.30 p.m.

Proposed Institute of Radio Engineers.

A general meeting was held in London, on 31st October, to discuss the advisability of continuing with the proposed Institute of Radio Engineers. The Chair was taken by Mr. James Nelson, M.I.E.E.

It is hoped to give a detailed report of the meeting in our next issue.

Volume II. E.W. & W.E.

The present volume (II.) of E.W. & W.E. will be completed with the next issue, which will be followed by both a numerical (Dewey system extension) index and the title index covering the fifteen issues from October, 1924, to December, 1925.

In the next issue there will be given details of binding cases for the complete volume.

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The Tantalum Rectifier.

By E. H. Robinson (2VW). **[R355·54**

Describing a series of experiments and the actual rectifier in use.

THAT a tantalum electrode immersed in a conducting solution shows a rectifying effect has been known for several years. The effect has been studied by a number of investigators, including Dr. Gunther Schulze, who made a prolonged study of the valve action not only of aluminium and tantalum, but a number of other metals in all sorts of electrolytes and under various conditions. Those who are interested in the details of this work are referred to *Science Abstracts* for the last twenty years.

For some reason the tantalum rectifier has not attracted much attention until quite recently; no doubt this is largely due to the expense incurred and difficulty experienced in obtaining tantalum metal. Further remarks on the latter subject will be found at the end of this article. The tantalum rectifier is very reliable, and the efficiency is quite good. The following remarks will help to give the reader an idea of its general properties.

The tantalum rectifier resembles the aluminium rectifier in its general principles, tantalum being used instead of aluminium and dilute sulphuric acid in place of ammonium phosphate; lead may be used as the other electrode. Current will pass from the acid to the tantalum freely, but only to a very small extent in the reverse direction unless the E.M.F. applied to the cell exceeds a certain maximum value, which may be anything from 40 to 200 volts according to conditions.

Before proceeding further, it may not be out of place to say a few words about tantalum itself. Chemically, tantalum falls into the same group as antimony, bismuth and niobium, but in many of its physical properties it resembles the platinum metals. It is one of the most resistant and refractory metals known. It is unattacked by any acid or mixture of acids, excepting, perhaps, hydrofluoric acid, and cold dilute alkalis are said to have no effect upon it. The writer found, to his cost, however, that a tantalum electrode acting as a rectifier in a strong solution of caustic soda became brittle and badly corroded after several hours' use. No such corrosion takes place with acid.

The melting point of tantalum is extremely high (about 2 300° C.), and it was used for filaments in electric lamps before the advent of the tungsten lamp. Commercial metallic tantalum has a dull, silvery appearance, rather like aluminium or platinum. Sheets of the metal a few mils thick are flexible and springy and may readily be cut to the required size with a pair of scissors.

Current Density.

In designing a rectifier for a given purpose, two of the most important things we need to know are the current-density allowable at the rectifying electrode and the voltage to which one cell will stand up. A current density of one ampere per square inch has been found to be quite suitable—that is to say, for every amp of rectified current to be delivered there should be a total area of one square inch of tantalum immersed in the solution (back and front surfaces of electrode being included).

Owing to the cost of tantalum, however, it might be politic to work with a still higher current-density, particularly in the case of high tension rectifiers, where a little extra resistance in the rectifier is not a very great objection.

It will be noted that the rating of one amp per square inch is considerably in excess of the working current-density usual in aluminium rectifiers. The question of the resistance of the rectifier cell and the consequent volt-drop is of particular importance in the case of low-tension rectifiers for charging accumulators. In charging a 6-volt accumulator through a rectifier it may be necessary to use an applied A.C. voltage of anything from 15 to 30 R.M.S. in order to push through sufficient amps, and considering that the resistance of most accumulators is a fraction of an ohm, this implies a poor efficiency. Hence it hardly pays to stint one's dimensions in a charging rectifier.

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Electrolyte Experiments.

The voltage allowable per cell depends to a large extent upon the electrolyte. For ordinary dilute sulphuric acid, which seems to be the best all-round electrolyte, there is not much reverse current when 120 volts (R.M.S.) of A.C. is applied to the cell; and for D.C. potentials applied in the reverse direction the voltage across the cell may be made much higher before an appreciable reverse current flows.

In spite of this it was found desirable to limit the voltage to between 60 and 80 volts per cell in the case of a high-tension rectifier. A higher voltage per cell gave rise to unsteady working and a fluctuating D.C. output. The exact strength of the acid is not critical, ordinary accumulator acid being perfectly satisfactory.

A few other electrolytes were tried in place of sulphuric acid, with varying results. Pure or slightly diluted nitric acid used in place of sulphuric acid allows higher voltages to be used, but at the same time gives the rectifier a higher resistance. A tantalum rectifier cell made up with nitric acid worked fairly well on an A.C. voltage of 150. On the whole, this advantage of nitric acid is outweighed by its practical disadvantages; the acid gives off fumes, and carbon must be used instead of the lead electrodes, as nitric acid corrodes all the commoner metals. A strong solution of caustic soda was tried in a rectifier cell built for charging purposes, and for a short time this appeared to be the ideal electrolyte for the job. The cell would only stand a maximum voltage of 40, but would deliver an ample D.C. output for a considerably smaller excess of transformer voltage than in the case of sulphuric acid. After a test run overnight, however, it was found that the tantalum electrodes were corroded and had become extremely brittle. This at once rules caustic alkalis right out.

Other solutions, such as common salt and potassium dichromate, were given a trial, but were found to offer no advantages. One sometimes sees statements to the effect that tantalum rectifies up to 500 volts or more in certain solutions. Such statements are apt to be misleading as they usually refer to D.C. tests made with very dilute solutions or with very small electrodes. As far as the writer has been able to ascertain at present, there is not much hope of making a practically useful tantalum rectifier to work at more than about 100 volts per cell. In the matter of maximum voltage the aluminium rectifier is superior, since a good cell of this type will work well at 150 volts and even as high as 200 volts under the best conditions.

Advantages of Tantalum.

The tantalum rectifier has some very important advantages over the familiar aluminium electrolytic rectifier. Firstly, the tantalum rectifier, once it is made up, requires practically no attention. The electrodes need no cleaning and the acid does not deteriorate; it is only necessary to add a little water at rare intervals to make up for electrolysis and evaporation. Since dilute sulphuric acid is one of the best conducting electrolytes known, the resistance of the rectifier is much lower than in the aluminium cell using ammonium phosphate. This implies a smaller voltage drop in the rectifier itself and offsets to a great extent the fact that the aluminium rectifier will work at higher voltages.

Another beneficial result of the lower resistance of the tantalum rectifier is a considerable reduction of heating up; this permits the use of smaller and more compact cells for a given power. As a matter of fact, the tantalum cell does not mind a reasonable amount of warming up—it somewhat increases the D.C. output if anything.

The tantalum rectifier "forms" almost at once. Only those who have spent hours trying to form a refractory aluminium rectifier can fully appreciate this advantage. It is sometimes stated that the forming of the tantalum electrode is instantaneous, but the writer has not found this to be invariably the case. The rectifier may pass quite a large reverse current for a few seconds, especially if the tantalum electrode has not been used before. This period rarely lasts more than a second or two, but it is just as well to provide a safety resistance in series when starting up for the first time.

When working at pressures over 40 volts the surface of the tantalum electrode scintillates in a similar manner to the aluminium in an aluminium rectifier. This scintillation unaccompanied by any sound is quite in order, but any excessively bright arcing, localised at one point and accompanied by a spluttering sound, indicates a too high voltage and results in an unsteady output. Seen in the dark, an aluminium rectifier

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electrode appears to be covered with a more or less uniform glow, while the tantalum rectifier electrode is mainly dark with isolated specks of light.

All the writer's tests on the tantalum rectifier have been made with a 50-cycle supply; the possibility of its use for higher periodicities still requires investigation. It was found recently* that the aluminium rectifier functioned to a considerable extent at 500 cycles provided that small electrodes were used. It is only reasonable to expect the same of tantalum. One of the limiting factors to the use of these high frequencies is the capacity effect of the rectifier. It will be recalled that a polarised aluminium electrode has an enormous capacity; tantalum is stated to show a similar effect. Incidentally, the writer is rather surprised that the experimental fraternity does not make more use of the electrolytic condenser. In this field aluminium easily holds its own against tantalum.

The Effect of Ferrous Sulphate.

It has been stated elsewhere that the addition of a small quantity of ferrous sulphate to the acid in a tantalum rectifier improves the efficiency. The following experiment made by the writer fully confirms this point. A full-cycle rectifier was made up by placing two tantalum electrodes and one lead electrode in a 3 lb. jam jar filled with dilute sulphuric acid, the tantalum electrodes being connected to the outer ends of the centre-tapped secondary of a step down transformer. The rectifier was used for charging a 6-volt accumulator which was connected in series with a D.C. ammeter between the lead electrode and the centre-tap of the transformer. The dimensions of each tantalum strip were 5 in. × ½ in. and the strength of the acid was about 20 per cent. as usual. The rectified current output was measured for different input voltages before and after the addition of ferrous sulphate. The results are tabulated below.

Without Ferrous Sulphate.

Volts across each half of centre-tapped Transformer.	Output D.C. Current.	Output load condition.
15 volts	2.6 amps.	No accumulator in output
25 ,,	6.0 ,,	
15 ,,	0.75 ,,	6-volt accumulator on charge
25 ,,	2.0 ,,	

After Addition of Ferrous Sulphate.

Volts across each half of centre-tapped Transformer.	Output D.C. Current.	Output load condition.
15 volts	8.2 amps.	No accumulator in output
25 ,,	12.3 ,,	
15 ,,	3.5 ,,	6-volt accumulator on charge
25 ,,	7.5 ,,	

The quantity of ferrous sulphate added was 3 fluid ounces of freshly-made and nearly saturated ferrous sulphate solution. The addition of 1 oz. made most of the difference; the second and third ounces produced very little extra effect.

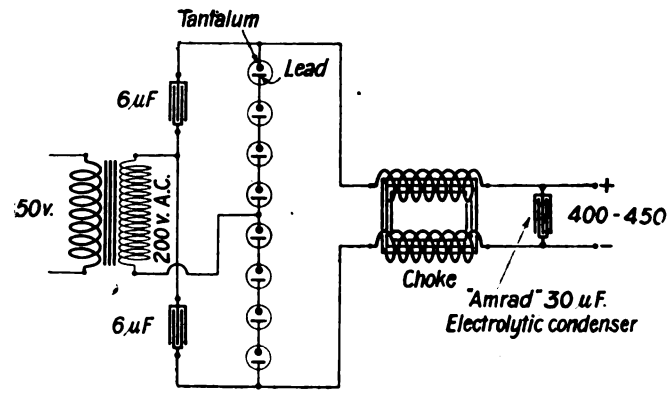

Fig. 1.

These figures show, then, that the addition of ferrous sulphate brings about an enormous improvement in the working of the tantalum rectifier. It reduces the internal resistance and also the heating effects in the rectifier. The ferrous sulphate therefore should never be omitted when a tantalum rectifier is being

* See E.W. & W.E., Vol. 1, No. 11, August, 1924.

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made up. It is better to add slightly too much ferrous sulphate than too little. The amount indicated by the above test is about one fluid ounce of saturated ferrous sulphate solution to every pint of acid.

The above experiment was made with a battery-charging rectifier but the same results apply to high-tension rectifiers as well.

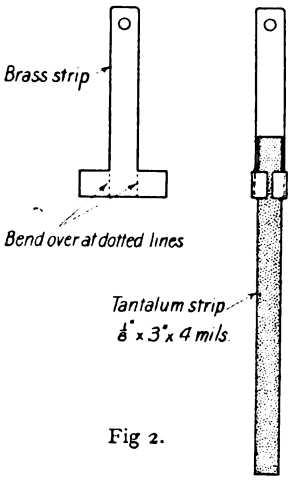

Fig 2.

A Description.

A brief description of the writer's own H.T. tantalum rectifier may be of interest. It is intended to deliver 50 milliamps of D.C. to a load at a voltage of 400. The connections are shown in Fig. 1. This is the voltage-doubling circuit and is preferred because it works well and allows a great saving in the number of rectifier cells necessary. The cells are made up in the familiar way with "boiling tubes," *i.e.*, test tubes six inches long and one inch diameter. The lead electrodes are strips half an inch wide reaching nearly to the bottom of the test tubes. The tantalum electrodes are strips three inches long and an eighth of an inch wide cut from 4-mil. sheet. Thinner sheet could easily be used and a considerably smaller electrode area would suffice for many purposes. In order to economise tantalum the strips are clamped to brass strips as shown in Fig. 2, the brass strips themselves being bolted to the tops of the adjoining lead electrodes.

About two inches of each tantalum strip is immersed in the acid. It is important to see that the brass holding strips are well out of contact with the acid. Three-quarters of an inch depth of paraffin oil is floated on top of the acid in each cell to arrest acid spray and protect the brass strips. The two 6μF condensers, shown in Fig. 1, are made up of a number of Mansbridge condensers in series-parallel.

Excellent final smoothing is obtained with a double choke and an "Amrad" electrolytic smoothing condenser. Running light, the rectifier does not absorb more than a few watts from the mains; the output when short-circuited readily delivers over 120 milliamps. The rectifier is always ready for use, and when switched on, does its work at once without fuss or bother. It has proved most useful and reliable for working power amplifiers, master oscillators and general experimental work.

In Praise of Atmospherics.

By J. F. Herd, A.M.I.E.E., M.I.R.E. **[R589**

The author quotes a lecture in which it was shown that atmospherics are of value in observations on meteorological phenomena.

MUCH has been written, and said, in condemnation of atmospherics, and it is novel to find anyone dealing with their more useful aspect. Yet this aspect has been admirably set forth in a recent lecture before the Royal Aeronautical Society, by Mr. R. A. Watson Watt, B.Sc., F.Inst.P., A.M.I.E.E., Superintendent of the Radio Research Board's Atmospherics Station at Slough. The text of the lecture has now been published in the Society's Journal (No. 170, Vol. XXIX, February, 1925), and reveals an interesting and highly-important correlation between directional observations on atmospherics and the meteorological conditions reported from the regions whence they appeared to originate.

For delivery before the Aeronautical Society, the paper naturally dealt with the subject particularly from the point of view of the application of such a system to the needs of aircraft, and devoted, to quote the author, "special attention to the aspect of the atmospheric in which it is to be regarded simply as a meteorological phenomenon, and to investigate the possibility of basing on its indications a thunderstorm warning

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service for the guidance of the aerial navigator who desires to steer clear of thunderstorms."

The paper then deals in considerable detail with observations on atmospherics made aurally as time and circumstances allowed at a group of direction-finding wireless stations arranged round the British Coast. In the two-year period under review there were a thousand cases when three or more of the stations were able to make observations within the same hour of the direction from which atmospherics were arriving. In about half of these cases the approximately simultaneous bearings gave intersections meeting more or less in a point, or in a small area, which would appear to be the region from which the atmospherics were then originating. The meteorological conditions then prevailing in or near these regions were subsequently examined, and the results set out in a table showing the percentage number of cases when some of the meteorological phenomena shown below were reported :—

(*a*) Thunderstorms within 250 kilometres.
(*b*) Thunderstorms within 1 000 kilometres.
(*c*) Hail showers within 200 kilometres.
(*d*) "Passing showers" within a similar distance.
(*e*) Squalls.
(*f*) Rainfall.
(*g*) Barometric minima.
(*h*) No correlation found.

The table can be briefly summarised into the following regions :—

A. British Isles.
B. South-west Europe.
C. Total for all Europe, Iceland, Atlantic, Mediterranean and North Africa, this division being made by the author on the strength of the decreasing adequacy of the meteorological data available. The results are then as follows :—

	No. of locations	a %	b %	c %	d %	e %	f %	g %	h %
A.	120	22	18	6	28	13	7	3	3
B.	373	30	9	3	13	6	20	9	10
C.	490	25	11	2	10	5	21	13	13

Twenty-five per cent. of the locations are thus definitely associated with comparatively-near thunder; an overall total of almost 40 per cent. are connected with either definite thunder or thundery conditions; and a total of 87 per cent. of all the locations are correlated with some of those meteorological conditions which form the basis of the frequent announcement "further outlook unsettled."

It must not be imagined that the above numbers represent the author's views or findings as regards the proportion of our received atmospherics which originate in thunderstorms. It merely states the proportion which have been correlated with *definitely reported thunderstorms.*

Considering these results, the paper points out that, had the above table as given for the British Isles been used as a means of thunderstorm warning, 50 per cent. would have provided valid warnings of considerable danger, and that in almost all the remaining 50 per cent., cautious aerial navigation would still have been necessary.

In addition to general discussion of these results, the paper quotes some special cases when almost spectacular agreement existed, both as regards space and time, between intersections from the directional stations and thunderstorms in various places, at distances ranging from 165 miles from the nearest to 1 200 miles from the farthest of the reporting stations.

The work on the directional observation of atmospherics was inaugurated by the Meteorological Office, from whom it was subsequently transferred to the Radio Research Board. A continuous directional recorder developed at the Board's Station at Aldershot (now transferred to Ditton Park) was then described and illustrated by slides at the lecture. Such a recorder had already been running at Aldershot for some 2½ years, when a second was installed at Lerwick, in the Shetland Islands.

On the first day of the conjoint running the charts from both recorders gave intersection off the Hebrides. From hour to hour the locations given by the intersections were followed across Scotland, Scandinavia, Mid- and East-Germany, all in close agreement with thunderstorms reported by the meteorological services. Finally, some 37 hours after its first appearance, the source as given by the intersections appeared to be on the Roumanian coast of the Black Sea.

On six other occasions during their first month of mutual running, intersections from both recorders located thunderstorms, subsequently confirmed from local observation.

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U2BRB. An Amateur Station.

By B. H. J. Kynaston. **[R625**

THIS description of one of the best American amateur stations will no doubt be of interest to the great number of wireless experimenters who have worked with U2BRB. The information, diagrams and photographs were kindly supplied by Mr. E. M. Glaser, the owner of the station, during my recent visit to New York. As I happened to be present just when he had decided to come down from 75 metres to 40 metres, information of both circuits can be given.

The station itself is situated in an upstairs room at Mr. Glaser's home, 845, East 13th Street, Brooklyn, N.Y., and consists of two transmitters, two receivers and two

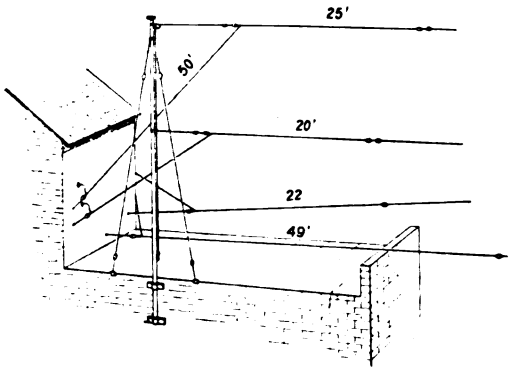

Fig. 1.

aerial systems. This allows for transmission and reception on short waves and the simultaneous reception of broadcast programmes in another part of the house. The transmitter does not interfere with the broadcast programme being received although situated so near to the receiver.

The aerial system used is shown in Fig. 1. The small aerial is used for 40-metre transmission and the other for 75-metre work. Whichever aerial is not being used, is switched on to the broadcast receiver. A single wire counterpoise as shown is used with both aerials. All the great distances reached by this station have been attained with the same single wire aerial. The lengths of aerial and counterpoise are shown in the diagram; the aerial is of No. 16 copper wire and the counterpoise of insulated wire of the same size.

Fig. 2 shows the circuits of the transmitter. It will be noticed that the well-known Hartley parallel feed circuit is used for both transmitters. A 250-watt German valve is at present being used, but a fifty-watter and an American 200-watt are also available.

There are two sources of high tension supply at this station, one being A.C. from the house lighting mains stepped up by means of a transformer to 1 200 volts and properly rectified by a chemical rectifier of fifty cells. The other source consists of a motor generator set which runs off the lighting mains and supplies H.T. at 2 000 volts. This motor generator set is installed in the cellar and is controlled from the wireless-room by means of a switch and relay. The high tension supply to the valve is controlled by means of a telegraph key and relay. Three keys are installed, two of the ordinary type, and one "side swiper" or "cootie key." Normally the station operates on about 200 watts, but when greater power is desired the two high tension supplies are connected together.

For the benefit of those desiring information as to the construction, Mr. Glaser has supplied the following details. The left-hand side of Fig. 2 shows the 40-metre transmitter. The dimensions of aerial and counterpoise have already been given. The two condensers in the aerial circuit are ordinary moving vane receiving condensers of .000 5μF maximum capacity. The coil L_1 is a spiral or pancake wound with ½-in.

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brass ribbon with a spacing of ½ in. There are 5 turns, the diameter of the inside turn being 7 ins. The coil is wound in slots cut in an ebonite strip as shown. The values of the other components of the 40-metre set are shown in the diagram. The primary coil, like the aerial coil, is wound with ½-in. brass ribbon and the inside turn has a 7-in. diameter.

The H.F. choke coils, both for 40 and 75 metres, consist of 20 turns of 24 D.C.C. wire wound on a 4-in. former. The grid condensers are of the usual mica type, .001μF capacity, and the leaks are G.E.C. 5 000 ohm resistances. The coils of the 75-metre transmitter are also spirals like those of the 40-metre set, but consist of a primary of 10 turns and an aerial coil of 8 turns. Each of these coils were originally mounted on 6 ebonite strips until it was discovered that a much greater aerial current could be obtained when only one supporting strip was used. For this reason the slots holding the ribbon are only cut to a depth of ⅛ in.

These coils and the valve are mounted at the back of a large ebonite panel. On the front of this panel the controls for the motor and the various meters are mounted.

The edge of the transmitting panel can be seen in the one photograph but there was not sufficient space to obtain a photograph of the transmitter without dismantling a good deal of the gear.

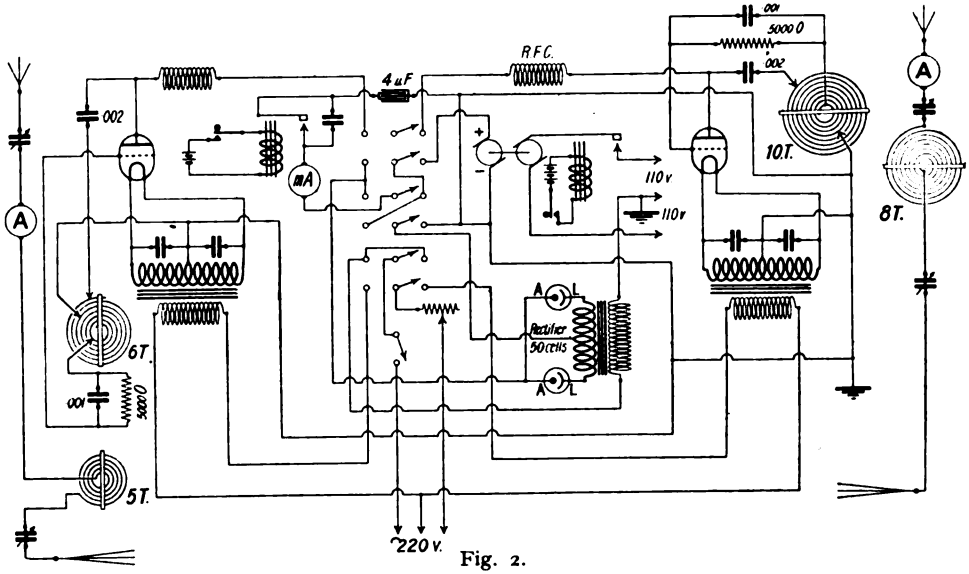

Fig. 2.

The short wave receiver (which covers 30-95 metres), like the transmitter, makes use of a Hartley parallel feed circuit and can be seen in Figs. 3 and 5, while Fig. 4 gives the diagram of the circuit. The values are as follows: The aerial coil (this is not shown in Fig. 3 but can be seen in Fig. 5) consists of 5 turns of No. 19 D.C.C. wire, space wound, and coupled very loosely to the secondary. These two coils were actually about six inches apart. The secondary coil consists of 17 turns of No. 20 D.C.C. wire space wound, and having a tapping, as shown in Fig. 4, between the eighth and ninth turn,

The H.F. choke coil consists of 60 turns of No. 22 D.C.C. wire on a cardboard former 2 in. in diameter. A tapping from the high tension battery is connected to this choke as shown, the full high tension supply being connected to the L.F. valves.

Fig. 3.

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Fig. 5 shows both the short wave receiver and the broadcast receiver. The latter embodies the usual regenerative circuit, with three L.F. valves.

Before concluding it would be as well to give a few details as to the normal range obtained by this station. The editor of the

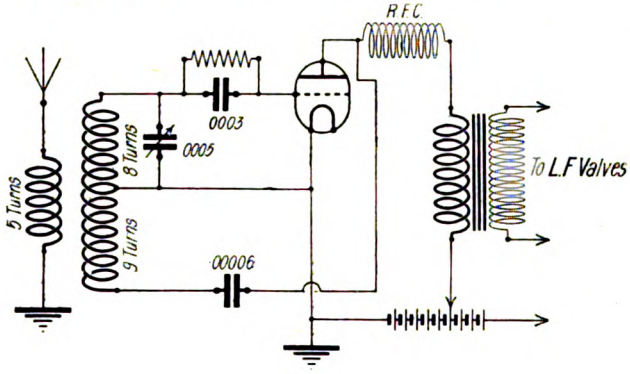

Fig. 4.

New York Telegram and *Evening Mail* asked a similar question to U2BRB a short while ago, and as he seemed to regard wireless amateurs' ranges as we often regard the size of anglers' fishes, Mr. Glaser let the representative of the paper work the station for eight hours.

He was shown the various controls and then left to it alone. A copy of his log for the eight hours is shown below.

Extract from Log 2BRB. *Sunday, 25th January,* 1925.

Weather clear. Wireless conditions fairly good, except QRM. W. A. Schudt operating station.

12.02 a.m. Heard British 5LF very loudly.

12.03 a.m. British 2KF calling A.R.R.L. We answered him and he reported us very loud.

12.25 a.m. British 5NN called us and we gave him two messages.

12.45 a.m. CQ from G2NM. English.

1.12 a.m. Cuban 2MK called us and gave us two messages.

1.32 a.m. CQ de Bermuda BER. We called him and immediately received a reply.

2.00 a.m. Worked French 8GO for fifty minutes and sent on message.

2.55 a.m. We connected with 7WM over Seattle way.

3.30 a.m. Talked with British 2JF.

4.10 a.m. Heard CQ from 4IO down South.

4.11 a.m. Heard 7DD very QSA Another W. Coast station.

4.12 a.m. We worked 6ADT of California. Reception bad.

4.40 a.m. We called New Zealand 2AC and received reply immediately. He told us to listen for 4AA.

5.20 a.m. Connected up with N.Z. 4AA. "Chewed fat" with him.

6.00 a.m. Hear New Zealand 4AG.

6.45 a.m. 9CLG calling Australian 3BQ.

6.50 a.m. We hear Australian 3BQ and called him.

6.52 a.m. Australian 3BQ answers us. Talked with him for awhile.

7.10 a.m. As soon as we finished with 3BQ Australian, 2DS called us. Sun was coming up and fading was bad. Worked for twenty minutes after sunrise.

Fig. 5.

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Rectifiers for High-Tension Supply.

Part IV: Arc Rectification at Atmospheric Pressure.

By R. Mines, B.Sc. **[R355·5**

I.—Ionisation Produced by Combustion.

THE gases entering a flame are undergoing a reaction which is exothemic, that is, heat energy is being liberated as an accompaniment of the reaction; this heat raises the temperature of the gases, and is carried away (at a rate equal to that at which it is generated, with a steady flame) partly by the products of combustion, and partly by radiation. This elevated temperature is the chief characteristic of a flame; and in general it is an essential condition for the chemical reaction to take place, thus a "vicious circle" is pursued.

A chemical reaction consists in a rearrangement of the constituent atoms (or groups of atoms, *i.e.*, "radicles") of the different kinds of molecules taking part in it. It is thus necessarily preceded by a "dissociation" of the molecules (followed eventually by a "recombination"). The action is analogous to that taking place when a salt is dissolved in water (as described in our previous article on "Electrolytic Rectifiers"[1]) and affords an explanation of the fact that considerable numbers of ions are generated in flames.*

In a Flewelling receiver that has recently been described, two flames with wire electrodes at their bases and tips were used as a grid-leak and anode resistance respectively; control of the resistance value was obtained by varying the height of the flame and so the extent to which the space between the two electrodes is rendered conducting by ions from the flame.

II.—The Vibrating Flame Rectifier.

On this principle, a flame may be used as a kind of switch, and with suitable modifications it may be made to rectify on the lines described in our previous article on "Mechanical Rectifiers."[2]

It has been found practicable to perform the "switching operation" by a vibrating flame playing between two electrodes (*e.g.*, two horizontal carbon rods). A gas flame is used, controlled by a "manometric capsule" (see Fig. 1), the diaphragm of which is fitted with a soft iron armature situated near the air-gap of an electromagnet. This magnet is fed with current taken from the supply to be rectified, with the result that the armature vibrates in the alternating flux; the pulsations are applied to the gas supply by the diaphragm and therefore the flame oscillates in synchronism.

To eliminate the square law response and the double frequency of vibration that would otherwise obtain, the electromagnet is polarised, either by passing a continuous current through a part of its winding, or by using a permanent magnet as core.

[1] E.W. & W.E., Vol. 2, p. 780. Sept., 1925.

*It is found that if a salt is introduced into the flame its conductance is very greatly enhanced, because the vaporised salt molecules do split up in the manner described at the high temperature. This statement is supported by the fact that the current that may be passed through the flame reaches a "saturation value" which is found to be the amount of current necessary to electrolyse all the salt supplied to the flame.

[2] E.W. & W.E., Vol. 2, p. 687. Aug., 1925.

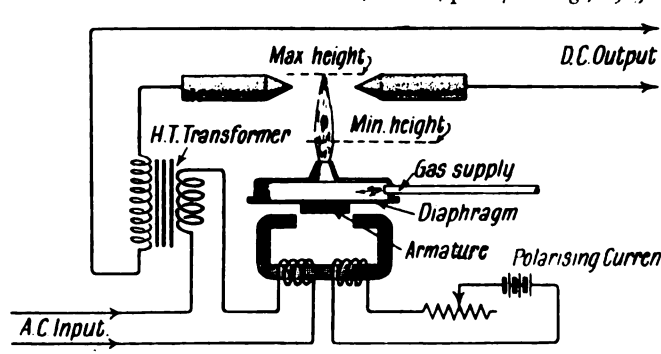

Fig. 1.

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In order to pass a reasonable current, a spark discharge is used (instead of a silent one, as suffices for a "grid-leak"). The separation of the electrodes is adjusted so that a spark will just not pass when the flame is smallest (say, 1 cm. high); during the other half cycle of the supply, the flame shoots up to, say, 10 cm. in height, and its tip reaches between the electrodes, ionising the gap and causing current to pass in the form of a spark.

Due to the use of a spark, the apparatus is suitable only for high P.D.s (for example, 6 000 volts), and the rectification is not complete.

III.—Thermionic Emissions.

It has been known since the 18th century that many solid substances emit ionised particles when their temperature is raised; the phenomenon may be described as normal evaporation (or sublimation) accompanied by ionisation of the resulting vapour. However, this ionisation, though it is facilitated by the higher temperature (involving greater "thermal agitation"), is not the result of chemical reaction among the molecules as in the case of fuming gases.

Thus metals emit positive ions in the first stages of increasing temperature, that is, a proportion of the vaporised molecules have lost an electron or so. This is not surprising when it is remembered that in metals at normal temperatures this is a condition that exists spontaneously (or is very easily brought about), and explains the ease with which these substances conduct electricity.

Further rise in temperature causes an emission of negative ions in addition, which at about 400°C. equals, and at higher temperatures by far exceeds, the rate of emission of positive ions. These negative ions are usually electrons unattached to any material particles—it is to these that the name *thermions* meaning "thermal ions," has been applied. It must be borne in mind that this "thermionic emission" is a phenomenon quite distinct from, and independent of, the evaporisation of material particles; whether these are positively charged or neutral.

These phenomena are also exhibited strongly by many "semi-conducting" substances, of the kind that show increased conductivity with rise of temperature (*i.e.*, having a negative temperature coefficient of resistance). Examples of these are the "oxides of the alkaline earths," as used on "oxide-coated" dull-emitting filaments.

IV.—The Arc Discharge.

Suppose that two electrodes, arranged for applying an electric stress to the gas between them, are raised in temperature sufficiently for them to emit copious supplies of electrons. It will be evident that under these circumstances the bombardment of an electrode surface or of gas molecules by positive ions are superseded as sources of supply of the negative ions. The amount of ionisation occurring in the gas when a P.D. is applied to it will become greater in proportion to the increased supply of electrons until, in the limit, the gas may become "saturated," that is, all the molecules of gas in the region of the discharge become carriers. Beyond this point any further increment of current can be carried only by the "thermions"; it is, in fact, found that in arc discharges as a rule the bulk of the current is carried by electrons.

V.—Vapour Conduction.

It is evident that with electrodes at this hypothetical high temperature there will be present in the path of the discharge some vaporised electrode material; this material is necessarily a conductor, which means, as we have stated above (Section III.), that its atoms easily lose planetary electrons. In other words, this vapour has a low ionisation potential, and as a result the discharge will pass with a much lower P.D. applied to the electrodes.

VI.—Maintaining the Electrode Temperature.

We have also noted that with this type of discharge the gas or vapour (whichever may be present) is saturated, that is, practically all of the molecules present are ionised, and are therefore disposed of by being driven along the potential gradient. Thus, in the absence of any other factors, the current is carried entirely by ions moving in one direction only, and only one electrode, the positive one or anode, is subjected to bombardment capable of maintaining it at a high temperature.

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It must be borne in mind, however, that evaporation from the (supposedly) hot electrodes is a continuous process—there is a continuous supply of vaporised molecules, which are ionised by the electron stream from the cathode as soon as they appear. These positive ions bombard the cathode and maintain its temperature. If this were not so, there would be no source of electrons, hence no bombardment of the anode, and so forth. Thus in the normal *arc discharge*, which is self-maintaining in the above-described manner, the actions follow a circle.

As is usual when cause follows from effect in a circle, the action will not commence spontaneously; in the case we are considering, it is necessary to heat the electrodes (or at least one of them, the cathode) initially before the arc can become established. This may in practice be very simply accomplished by touching the electrodes together at some point while connected to a suitable circuit for maintaining the necessary P.D. across them; heating takes place at the contact, and on separating the electrodes this is sufficient to cause a "hot spot" that will give rise to evaporation and thermionic emission. It was in this manner that the arc was first discovered.

VII.—Asymmetry of the Arc Discharge.

In the *carbon arc*, for example, the electrons so far outnumber the positive ions that the anode, which they bombard, is kept at a temperature considerably higher than that of the cathode; in addition the hot area (or "crater") of the anode is much the larger. It is found in fact that about 85 per cent. of the light emitted is due to the positive crater; 10 per cent. only comes from the negative crater, the arc itself accounting for the remainder.

We have seen, however, that it is the negative crater whose high temperature is the essential condition: it is in fact possible to maintain a proper arc with the anode quite cold; the only possible difference is that there may be little or no electrode vapour in the arc, but this will always be compensated by diffusion into the arc of neutral gas molecules from the surrounding atmosphere, resulting in a higher potential drop in the arc. Actually, quite a sufficient supply of vapour may come from the cathode itself, the neutral molecules on evaporation being ejected into the arc space (*i.e.*, in the direction of the anode) prior to being ionised and drawn back to the cathode as positive ions. (This condition is exhibited to a maximum extent by the Mercury Vapour Arc operating under reduced pressure.)

VIII.—Rectification in the Arc.

If then by any means one electrode is cooled, an asymmetry is introduced, which may be put to practical use for rectification. Thus if an alternating P.D. is applied to the electrodes in place of a steady P.D., all will go well so long as the cooler electrode is positive; but when the P.D. reverses for the next half cycle the arc tends to "go out," because the cooler electrode will not emit electrons in sufficient quantity—in fact, the current flowing in the second half cycle is only a fraction of that in the first.

This condition is evidently one of "imperfect" rectification. In practice it is not possible (without the introduction of additional factors hitherto unconsidered) to reduce the "inverse current" to zero, for if complete extinction of the arc were permitted the cathode proper would cool down from its necessarily high temperature during the interim and the arc would not be able to re-establish itself at the commencement of the next cycle.

IX.—Effect of Electrode Material.

The character of the arc is considerably effected by the physical properties of the materials used for the electrodes. The equilibrium temperature attained by the cathode at its hot spot, the seat of the arc (and by the anode, too, in the absence of undue cooling) is dependent on the boiling point of the material—in general, the actual temperature of the vapour in the arc is not far removed from the boiling point. The higher the temperature attained by the electrodes, the faster is their rate of cooling if the arc is allowed to go out during the second half cycle. This rate of cooling is also dependent on the specific heat and on the thermal conductivity of the material, and to a smaller extent on its emissive properties as a heat radiator.

The properties of the electrode material will determine the minimum current with which an arc can be kept in existence—and this is the minimum inverse current attainable in the absence of independent means for maintaining the electrode temperature.

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An easy way of introducing the asymmetry required for rectification is to use different materials for the two electrodes; the anode, for example, can be chosen with a high heat conductivity and a high specific heat—it will then tend to keep itself cool without artificial means.

X.—Conditions for Perfect Rectification.

Perfect rectification means zero inverse current, and this can be attained only by extinction of the arc. The achievement

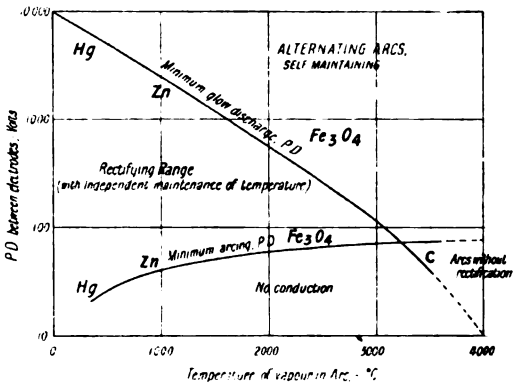


Fig. 2.

of this result can be assured most simply, whilst at the same time making the apparatus as a whole self-maintaining, by using multiple anodes with a single common cathode—on the lines described in our previous article.[3]

With this arrangement the arc is in continuous operation, playing always upon the one cathode, but on one anode only at a time (so that with respect to the remaining anodes it is "extinguished" in so far as no conduction takes place). Under these circumstances the anodes may be quite "cold," or, rather, they must be incapable of supplying electrons in any quantity by thermionic emission or otherwise.

The accompanying Fig. 2 gives an idea of the rectification conditions obtainable with different materials; in this case, the materials used for the two electrodes do not differ greatly in their properties. The lower curve gives the P.D. below which it is not possible to maintain an arc discharge.

The upper curve gives the minimum P.D. required for a discharge (other than an arc) to pass between the electrodes of sufficient intensity to heat the electrodes to the point where an arc discharge can set in.

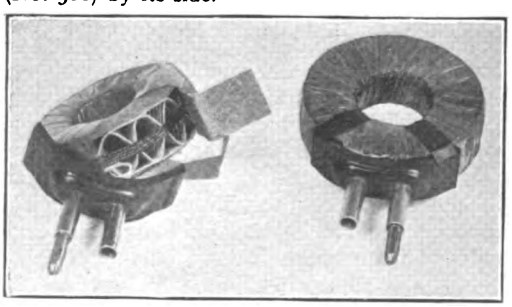
If the P.D. rises above that indicated by the upper curve, an alternating arc will be set up, but no rectification will ensue; if it lies at a value between the two curves, then rectification is obtainable, but some auxiliary means must be available for maintaining the cathode temperature (*e.g.*, an electrically heated filament, as in the "Tungar" Rectifier).

[3] E.W. & W.E., Vol. 2, pp. 783, 784, Sept., 1925.

The O'Keeffe Plug-in Coils.

THESE coils, of which we have received a set for test, are manufactured by the Dickinson Electrical Manufacturing Co., Ltd., of Graham Road Works, Bexley Heath, Kent, who are the patentees.

A feature of the construction is that there is no great difference in size between any of them, as will be seen from our illustration which shows the smallest (No. 25) partially dissected, and the largest (No. 500) by its side.



The smallest and largest of the O'Keeffe coils. The construction can be plainly seen from the former.

This uniformity is a good point, and it seems to have been attained without appreciable loss of efficiency. Other good points which make themselves apparent on casual observation are that the coil mounting has a minimum amount of solid dielectric between the sockets; the fitting is made reversible by the use of a loose plug fitting into the sockets, and the coil itself is completely enclosed by windings of red empire silk.

We noticed in one or two cases that the plugs and sockets were rather roughly finished—a little attention to this point would be advisable.

We confined our tests to two coils, the No. 50 and No. 500. The former had an inductance of 178.5μH, a H.F. resistance of 10.1 ohms, a self-capacity of 10$\mu\mu$F, and a power factor of .013. For the latter coil the corresponding results were 12 480μH, 149 ohms, 20$\mu\mu$F and .023.

Interpreting these results in the light of those obtained from other coils tested, we can say without doubt that they are quite good. In fact, in only one or two cases of plug-in coils tested have these results been surpassed The prices of the coils range from 3s. 6d. for the No. 25 to 9s. for the No. 500.

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Wireless, the Moon and the Barometer.

By W. J. Turberville-Crewe. **[R113·8**

EVERY experimenter knows at least something of the action of the sun's rays, ionisation of the ether, the Heaviside layer, etc., etc.; but I wonder how many have logged results against the phases of the moon and the barometric readings?

Some months ago G6LJ showed me a very interesting chart that he had prepared, in which he had carefully plotted the number of DX stations he had received each night for over twelve months. We had a lengthy argument, in consultation with the calendar, finally coming to the conclusion that the phases of the moon had a very definite effect upon wireless waves.

Again, Canadiau 3GG has been carefully plotting barometric readings in the same way and has derived some pretty conclusive evidence of conditions being largely dependent on a steady pressure.

With regard to the moon, other things being equal, it would appear that the waning period seems to favour DX: but, as really good work has frequently been done on a bright moonlight night, it will be as well to study the barometric effect more closely. If the weather really does affect DX reception, what we want to know is what sort of weather will give us the best results and what is the brand that spirits away our signals and makes our sets inoperative.

Now, to get fair comparisons of this description and to eliminate as far as possible the chances of error in the reckonings, one must make tests with the receiver constant. It is of little use chopping and changing values—circuit, wave-length, etc.—and the H.T. and L.T. supply should be as free from fluctuations as it is possible to make it. Tests should be arranged for a definite time at definite intervals in conjunction with definite stations. Two-way communication will be helpful as results may vary east or west.

Three logs should be kept in graph form for ease of reference:—

(1) Strength of signal on audibility meter plotted against date and phase of moon;.

(2) Barometric reading against date and time;

(3) Number of DX stations logged in a fixed time against date.

If the readings of a barometer are taken every few hours and plotted on squared paper, it will be found that the pressure of the atmosphere is constantly changing in an irregular manner from day to day and hour to hour. One must bear in mind that the "glass" does not tell the present so much as the future—say the coming 24 to 48 hours.

Many enthusiasts clamour for clear, bright nights, whilst others prefer dark and cloudy spells. The majority, however, seem to favour a night with low-lying rain or snow clouds following a dull day in which the sun has not had the chance to suck most of the life out of the air.

Since distant reception is often excellent during a deluge there are no statistics to show whether rain helps or hinders the penetration of wireless waves. On the other hand a few occasions have been recorded when reception has not been at all good during a rain storm. Blizzards usually affect reception pretty badly; but one can scarcely blame the blizzard if it is recalled that it is the result of a falling barometer.

Fading is often reported during wind, and a deal of it can be attributed to a swinging aerial. There is, however, another possible explanation: to investigate this phenomenon intelligently a careful study must be made of the Heaviside layer theory. It is well known that in distant reception the ray reflected by the Heavyside layer is far stronger than the direct ray, even if the latter is received at all. If the position of the layer is shifting at all rapidly, it naturally follows that the angle of refraction will change in sympathy; and thus the intensity of the signal will also vary.

Another channel of investigation that will suggest itself is that of the Northern Lights. About these practically nothing is known from the wireless standpoint save that static is prone to rise in intensity on occasions during their continuance.

To sum up the position in a nutshell it would appear that (1) a waning moon is helpful to good DX reception; that (2) depressions of the barometer are bad; that (3) a steady rise after a fall is good.

Who will come to the rescue and tell us for certain what are the ideal atmospheric conditions for best work?

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The Radio Relative Subject Index.

Compiled by [025·4

R. Borlase Matthews, Wh.Ex., A.M.Inst.C.E., M.I.E.E., F.R.Ae.S.

It should be borne in mind that the letter R really represents the figure 621·384. This must be remembered when filing wireless data with other data so as to get everything into correct numerical order.

Editorial Note.

IT will be remembered that in our issues of October, 1924, to April, 1925, we published the sections of a complete classification of wireless subjects, so that those who take the trouble to collect and file away information on the subject could do so in a systematic manner. In introducing this classification, we promised to provide in due course an alphabetical index to it, so that any definite subject could be put in the right place and found again.

Readers not experienced in filing work may naturally ask: "If an alphabetical index is needed, why not file away matter in alphabetical order and be done with it?" The answer is that the *logical* arrangement of the decimal classification is of enormous assistance by bringing allied subjects together. For example, "Amplifier, H.F." and "Transformers H.F." are a long way apart in the alphabet, but can be kept together in a logical classification.

In fact, the consistent user of the Decimal Classification soon gets to know the main divisions, and can turn up, off-hand, any desired subject. But for those just beginning to use it an alphabetical key to subjects is very valuable.

In our particular case, there is a further point. We propose, when preparing the index to Vol. II. of E.W. & W.E. (which will be complete at the end of the year) to provide, in addition to an alphabetical index, also a decimal index to the contents. By doing this we shall facilitate research. Thus, suppose a reader wishes to find what has been said about Amplification throughout the volume. On looking up "amplification" in the subject-index *to the classification*, which we print now, we find several numbers, grouped about R132 and R342. Then, referring to these numbers in the Decimal Index to E.W. & W.E., Vol. II., when it appears, there will be found references to all articles, *whatever their titles may have been*, bearing on the subject.

This is obviously simpler than finding in an alphabetical index articles on, say, "Distortion in Amplifiers," "The Perfect Set," "Stability in Amplifiers," and other titles.

With these remarks we will pass on to the Index, just remarking that its compilation from the classification itself as published in E.W. & W.E., has been both a laborious and a difficult task, admirably carried out by Mr. Matthews, who is an expert in both Classification and Wireless matters, as well as other things such as making two blades of grass grow where one grew before!

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ERRATA.

Our attention has been drawn to a printer's error which occurred in Appendix I. to the first part of the article on "Distortion in Wireless Telephony," by Messrs. E. K. Sandeman and N. Kipping (E.W. & W.E., September, page 764).

In the second line of equation (5)

$-\frac{KE}{2}\cos^2(c+v)t$ should read $+\frac{K^2E^2}{4}\cos^2(c+v)t$.

In addition, on page 758, in the last line of paragraph 2, column 2, the word "not" should be "now."

Lastly, we have been asked to point out that our statement with regard to the Marconi D.E.R. valve in the review of the Albert Hall Show (in the last issue) was incorrect. This valve, we are informed, is still marketed by the Marconiphone Company as a "general purpose" valve, the other models mentioned being additional.

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The Horticultural Hall Exhibition.

A general review, showing the present trend in the design of apparatus.

[R064

THE second London wireless exhibition this year, staged at the Horticultural Hall, Westminster, was a smaller one than that held some time previously at the Albert Hall, which was described last month.

Despite this, however, the exhibits were very interesting and in the following pages it is proposed to describe the general trend in the design of sets and components which was revealed by an inspection of the apparatus in the exhibition.

Broadcast receiver design was on much the same lines as was indicated at the previous show. In the present one the firms exhibiting were, on the whole, smaller concerns, and for this reason the handsome and costly "luxury appeal" sets were not so prominent. Several of the larger firms, however, were showing some handsome receivers, notably Messrs. Peter Curtis, Messrs. Rotax, Messrs. Read & Morris, and Messrs. R. F. Graham. Most of the circuits employed by these makers followed conventional lines, though in some cases there was incorporated some novelty in design.

Messrs. Rotax have made some attempt at increased selectivity in their "Rotola" III. receiver by incorporating a simple wavetrap, which may be used, or not, at will. Messrs. Read & Morris make a range of receivers for which the filament and H.T. supplies are obtained from the lighting mains simply by plugging into a socket. The unit which renders this possible is contained in the set, though it is also obtainable separately. Unfortunately, details as to the construction of this were not obtainable. Two types were made, for D.C. or A.C. supplies. Messrs. R. F. Graham make a set which is fitted in a Broadwood cabinet. The novelty is that the loudspeaker, which is contained in the set, is carved from a solid block of wood by Messrs. Broadwood. Messrs. C. F. Elwell were also well to the fore with a range of the well-known "Aristophone" receivers.

Most of the other firms were showing ordinary broadcast receivers of some description, and it was noticed that in many cases some attempts had been made to secure purity of reception. Messrs. Seagull, Ltd., were showing some sets in which the L.F. valves were coupled by the choke-capacity method, which with well-designed chokes of high inductance and low self-capacity is quite successful, though not so powerful, stage for stage, as good transformer coupling. The chokes as used in these sets are also sold separately, and an N.P.L. amplification curve which is exhibited shows an amplification factor of 8 (with the valve used) which is practically constant for all frequencies between 250 and 4 000 cycles.

The Broadwood-Graham cabinet receiver. The loudspeaker horn is carved from a solid block of wood.

Generally, it was found that it was the exception rather than the rule, to find receivers employing L.F. amplification which had no provision for grid bias and extra H.T. voltage on the L.F. valves. In most cases, too, it was found that power valves for the L.F. stages were either supplied or specified. There is no doubt that manufacturers are at last realising the fact that the ability to receive a station is not everything—quality counts.

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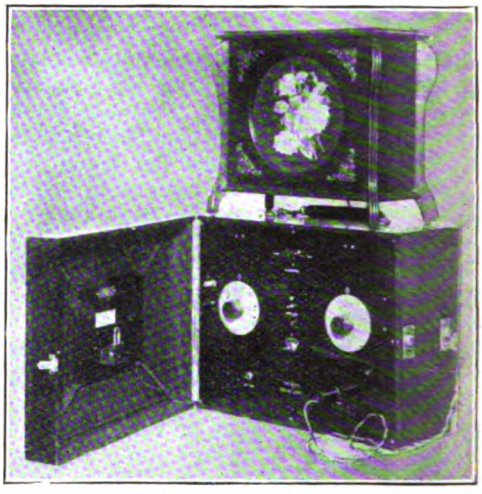
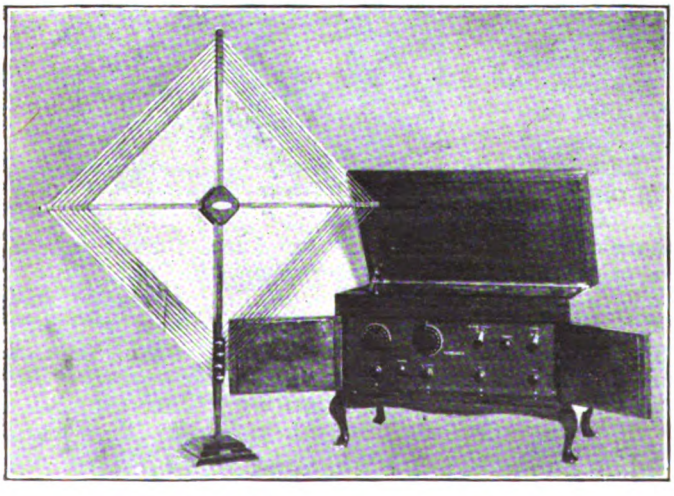
This being the case, it was remarkable that in only one case did we see a set in which crystal rectification was employed, other than in crystal sets themselves. We have consistently stated, and still maintain, that a crystal detector, preceded by an H.F. valve where necessary, and followed by well designed L.F. stages, will give the best possible tone in the reception of telephony. The days of the insensitive and unstable crystal are over—witness the large numbers of really good crystals at the Show, and the many permanent and semi-permanent detectors. The "Harmo" detector, shown by the Sclerine Crystal Co., is permanent and sensitive. The former property may be verified by throwing the detector about, or dropping it on the floor!

As was expected, supersonic receivers and sets of parts for constructing the same were largely in evidence. Most of these followed the usual lines, namely, a detector and oscillator, followed by three or four intermediate frequency stages (one of these often being tuned), the second detector, and one or two L.F. stages.

The "Super-Het. 8," manufactured by Messrs. Peter Curtis, Ltd., is novel in that it represents an attempt on the part of the makers to design a set which will be particularly suitable for use in this country. It has been realised that many wireless amateurs spend a large part of their time in listening to the local station, and for this purpose a supersonic receiver is not only unnecessary, but costly in valves and batteries. For this reason the makers have incorporated two switches, by means of which the oscillator, one detector and the I.F. valves are cut out, leaving a straight 2 or 3-valve receiver for local station work. The complete receiver employs 8 valves: detector, oscillator, 3 I.F., 2nd detector and 2 L.F. Tuning controls are two in number. A 2-valve oscillator unit is also available which, with a receiver employing two or more H.F. valves, constitutes a supersonic set. The supersonic components are also sold separately.



A luxury portable set. That of the M.P.A. (Wireless), Ltd. The loud-speaker standing on it is manufactured under the Celestion patents.



The Peter Curtis 8-valve supersonic receiver and frame. It has several novel features.

The Igranic Company are also selling boxed sets of parts for the construction of a supersonic receiver. This employs 6 valves, and a special reactance-capacity coupling unit which is said to be very stable in action, constitutes the coupling for the I.F. valves. A wide wave-length range (215—4 500 metres) is made possible by the use of three interchangeable oscillator units. The Western Electric Company are also showing a supersonic receiver, using 7 Wecovalves, with a wave-length range of 300 to 3 000 metres, controlled by switches. One of these sets

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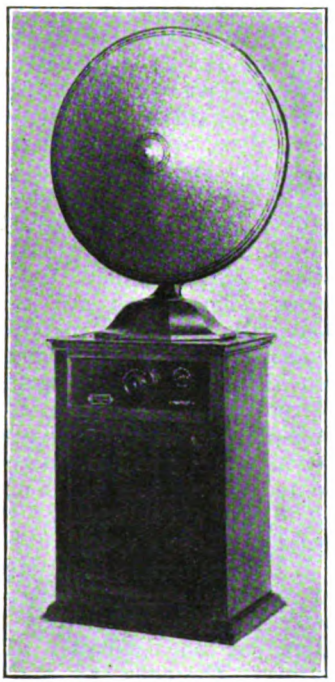
has recently been taken on a tour round Europe in a car, and the original valves are still intact.

Before leaving the subject of receivers, it should be mentioned that portable sets were in strong evidence at the Show, most of the firms showing one or more.



The Western Electric "Kone" loud-speaker and amplifier.

Turning now to the subject of loud-speakers, novelties in design were not so noticeable as at the previous Show. The general tendency seemed to be towards the improvement, both as regards tone and appearance of existing models, coupled with reduction in prices. One novelty was outstanding, namely, the "Kone" loud-speaker by the Western Electric Company. This was a feature of the firm's exhibit. The instrument is of the hornless type with a double-conical diaphragm, about 18 in. in diameter the back cone being truncated to permit the placing of the specially designed electro-magnetic system within. The absence of a horn renders it practically non-directional. In preliminary tests of this instrument we were impressed by its performance, speech being particularly well reproduced. The resistance of the windings is 750 ohms and the impedance at speech frequencies approximately 5 000 ohms. Special power amplifiers are being produced for use with the "Kone," and are available in panel or cabinet form. During the exhibition, some of the "Kone" loud-speakers, together with a larger model of the same, were reproducing orchestral music played elsewhere in the building.

Another novel loud-speaker is the "Statophone" produced by Messrs. C. F. Elwell, and sold with a built-in set. Details of its construction were not available, but it is understood that the action is entirely electrostatic. The conventional electro-magnetic system with a diaphragm or reed has been replaced by a light metallic membrane, which presumably moves under the force of electrostatic attraction, the principle being similar to that employed in electrostatic voltmeters.

Several cabinet and hornless loud-speakers were also noticed, notably those by S. G. Brown, C.A.C. Radio (the "Violina") and W. Bullen.

Batteries and other sources of L.T. and H.T. supply now claim our attention, and here the most striking point was the tendency shown by makers to introduce accumulator high-tension batteries, of which many were on view. There is no doubt that the increasing use of high-powered sets and power valves will in time render the use of these (or H.T. supply from the mains) necessary. Dry batteries of large capacity only partly solve the problem.

Several H.T. and L.T. supply units were to be seen—most of these were for D.C. mains only, and did not appear to embody any new principles. Rectifiers, of the rotary type, for accumulator charging from A.C. mains were present on at least two stands.

The Elwell Statophone. The loud-speaker operates electrostatically.

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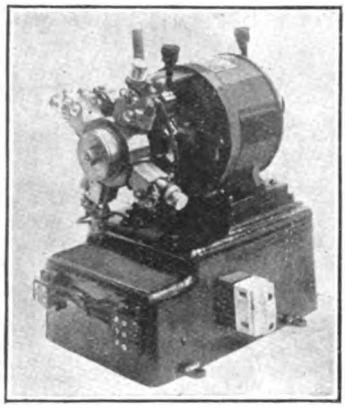
Valves were to be seen on several stands, though, with one or two exceptions, no new types were to be seen. Power valves are now made by almost all the makers, a 525 or 5-volt power, being a great favourite. The 525*b*, or high magnification ditto, is also frequently met. The Nelson Electric Company, have produced a series of three-filament valves, with double flat plates and



One of the "M.W." rotary rectifiers for accumulator charging. Many types are made.

grids. A neat scissor switch at the base enables different filaments to be used, or two filaments at once. In the latter case, the valve can be used as a power valve, since the total emission is increased, and the plate impedance is lowered.

Manufacturers are beginning to realise that an efficient tuner is an essential where long-distance reception is concerned.

Coils of many types were to be seen, and most of them appeared to be well-designed from the point of view of low self-capacity. Quite a number, however, were very flimsy in character. For serious work, coils must be robust and capable of remaining substantially constant in inductance and self-capacity. For this reason, enclosed types are preferable providing the covering does not introduce dielectric losses.

A survey of the condensers at the Show indicated clearly that the square-law type is very popular—in fact, it is now almost impossible to buy one of the ordinary type, apart from laboratory instruments.

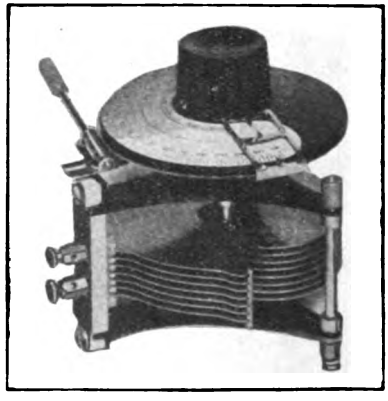
The single-plate "vernier" is disappearing —in its place is the slow-motion device, either built into the condenser, or applied by means of a special geared dial. This is a great improvement—the difficulty of accurately logging a station, when using a separate "vernier," is well-known.

At the same time it should be pointed out that for supersonic work, particularly for the oscillator condenser, control is exceedingly critical, and a reduction of at least 80 to 1 is almost essential. Some of the slow-motion devices only give an 8 to 1 or 16 to 1 reduction, which for this purpose is not sufficient. Many of the devices shown were spoilt by backlash.

With regard to the design of the condensers themselves, we noticed several really well-designed instruments, notably those by the Igranic Company and the Formo Company. In the latter case, the two sets of vanes are complete units, the separate vanes being bonded together by metal strips. The vanes are thus quite rigid. The only insulating material in the whole instrument is a small strip of pure (not moulded) bakelite, so losses should be small.

Another novel condenser is the Newey four-point shown by Pettigrew and Merriman. It contains two sets of square vanes, mounted on toothed sectors, which are both operated by a gear wheel attached to the knob and spindle. A square-law effect is produced.

L.F. transformers as a general rule followed conventional lines, totally enclosed types being common. A novelty was seen in the shape of the Microhm Toroidal Transformer. The coils are wound in an ebonite



The new Formo-denser, by the Formo Company. It has several novel features.

ring, and are of small cross-section. The core is in four distinct sections, arranged at intervals of 90° round the ring, which they embrace. It is said that the self-capacity of the windings is extremely low, coupling between the coils is very tight, and no external field is produced. It will be interesting to test this transformer, for which distortionless amplification is claimed.

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On the Application of the Neon Lamp to the Measurements of Leaky Condensers and very High Resistances.

By J. Taylor, B.Sc. **[R220, R240, R337**

Introduction.

A METHOD for the comparison of capacities and high resistances was described in a previous issue of this journal.[1] In the method referred to the capacity was shunted across the neon lamp, which was placed in series with a high resistance, and a battery of sufficiently high voltage to drive the lamp. With this arrangement "flashing" occurs at regular intervals of time, and this regularity of "flashing" is utilised for the comparison of capacities and high resistances.

There is, however, an alternative position of the condenser—across the circuit resistance, as shown in Fig. 1—which has several advantages over the previous position for the comparison of capacities and resistances. It will be well, perhaps, to give the theory of this method. (The theory of the other capacity position is very similar.)

Theory of the Method.

The theory of the position where the capacity is across the lamp has been put forward previously.[2] It is shown in the paper referred to that the current through a neon lamp connected to a supply of voltage, may be represented by the linear relation,

$$i = k(V - V_a) \quad .. \quad .. \quad (1)$$

where i is the current through the lamp, V is the potential across its terminals at any instant, V_a is the cathode fall of potential approximately, and k is a constant which may be termed the conductance of the lamp.

The production of "flashes" in the neon lamp has been the subject of previous articles in this journal, so that it is not necessary to enter into the causes of the phenomenon again. Further, the nomenclature is the same as in the previous papers.[3]

Referring to Fig. 1 it is obvious that, if E is the voltage of the charging battery, and C the magnitude of the capacity, the potential across C at any instant is,

$$V_1 = E - V.$$

Now the quantity of electricity dq_1 flowing

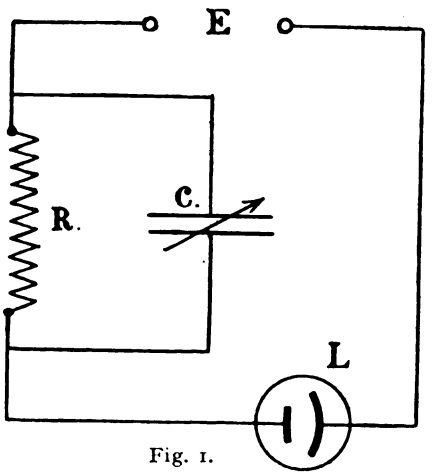

Fig. 1.

into the condenser in dt. secs. *via* the lamp is evidently

$$dq_1 = K(V - V_a).\,dt. \quad \text{(From equation (1))}$$

and the quantity dq_2 flowing out of C *via* the resistance in the same time is evidently,

$$dq_2 = \frac{V_1}{R}.dt = \frac{E - V}{R}.\,dt.$$

Therefore the net gain of condenser charge dq, is given by,

$$dq = dq_1 - dq_2 = C.d.\,R = k\,(V - V_a).\,dt - \frac{E - V}{R}\,dt. \quad (2)$$

Or we may write,

$$\frac{dV}{(kR + 1)V - (E + kRV_a)} = -\frac{1}{CR}dt. \quad .. \quad (3)$$

[1] Vol. 2, No. 14, p. 97. Clarkson & Taylor. Also see *Journ. Scien. Instrs.* Vol. 1. p. 173, Taylor & Clarkson.

[2] *Journ. Scien. Instrs., loc. cit.*

[3] E.W. & W.E., Vol. 2, No. 13, p. 41. Taylor.

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Integrating equation (3) and writing

$$D = \frac{(E + kRV_a)}{(1 + kR)},$$

we obtain

$$-\frac{t}{CR} = \frac{1}{(1 + kR)} . \log_e (V - D). \quad .. \quad (4)$$

The condenser charges up till the voltage V across the lamp is equal to the lower critical voltage V_b, and then discharges till V is equal to V_c, the upper critical voltage; so that if t is the duration in secs. of the luminous period, we have from equation (4)

$$t_1 = \frac{CR}{(1 + kR)} \cdot \log_e \frac{V_c - D}{V_b - D}. \quad .. \quad (5)$$

Now during discharge of C through R in the "dark" period we have

$$-C.dV = \frac{E - V}{R} dt.,$$

and integrating from $V = V_c$, to $V = V_b$, we obtain

$$-\frac{t_2}{CR} = \log_e \frac{E - V_c}{E - V_b} \quad .. \quad .. \quad (6)$$

it being the duration in secs. of the "dark" period.

We have, therefore, from equations (5) and (6) that the total time period T ($T = t_1 + t_2$) is given by

$$T = CR.\log_e \frac{E - V_b}{E - V_c} + \frac{CR.}{(1 + kR)} . \log_e \frac{V_c - D}{V_b - D}. \quad (7)$$

This is an exactly similar relation to that obtained for the other condenser position, and it may, on certain assumptions, be reduced to the form

$$T = CR. \log_e \frac{E - V_b}{E - V_c} + C\Delta. \quad .. \quad (8)$$

where Δ is a constant for a fixed value of the charging voltage E.

It will be readily seen from equation (8) that T is a linear function of R (for fixed values of E and C), and of C (for fixed values of E and R). The graphs of these functions are thus straight lines. Now the second term of equation (7) is negligibly small compared with the first (when the "flashes" are of easily countable order), and so we may write the equation fairly accurately in the form,

$$T = CR.\log_e \frac{E - V_b}{E - V_c}. \quad .. \quad .. \quad (9)$$

The above position of the capacity has the additional advantage that there is no variation of V_b with the capacity,[4] since the latter is not across the lamp terminals.

Overcoming the Disabilities of the Neon Lamp Methods.

The writer pointed out in a letter[5] that erraticity in the time of the "flashes" produced in the lamps is largely attributable to a "lag" in the actual occurrence of the "flash" or discharge behind the voltage producing it, due to the lack of sufficient ionisation within the lamp to allow the discharge to pass when the upper critical voltage value across the lamp has been attained. This "lag" may be overcome by having a bright light, neon lamp, or radio-active substance, in the near vicinity of the experimental lamp. These agents produce sufficient ionisation within the lamp to ensure that the discharge takes place without a "lag." If the above precautions be adopted, "flashes" of very long time period (a minute or so) and of regular and repeatable duration may be obtained.

In order to obtain consistent and repeatable results, the lamps are stabilised by "over-running" them before use on a high voltage (480 volts is suitable), so that the electrodes become red hot, and the impurities are driven off from them. After being treated in this manner and rested for a day or two, the lamps exhibit much greater steadiness of their constants, and are less prone to progressive variations.

Experimental Results.

It is found experimentally that both the T, C graphs (E and R constant), and the T, R graphs (E and C constant) for the position of the capacity across the resistance pass through the origin—within the limits of experimental error—and are very exactly straight lines. These results are seen to be in accordance with the relation of equation (9).

Application to the Measurement of Leaky Capacities.

We may assume that a leaky capacity is equivalent to a non-leaky capacity shunted by a high resistance of value R_x megohms. Let C_x be the magnitude of the capacity.

[4] For the determination of the variation of V_b with the capacity, see Taylor and Stephenson's *Journ. Scien. of Instrs.*

[5] E.W. & W.E. Correspondence, vol. 2, No. 14, p. 121.

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If we place the capacity in the position given in Fig. 1, and further place a resistance R, of magnitude suitably high to give "flashes" conveniently countable, across the capacity terminals, we have from equation (9),

$$T_x = C_x \left[\frac{RR_x}{R+R_x}\right] log_e \frac{E-V_b}{E-V_c} \quad .. (10)$$

where T_x is the time of "flash."

If we put an additional capacity (non-leaky) of magnitude C_1, in parallel with C_x, we have, with obvious notation,

$$T_1 = (C_x + C_1) \left[\frac{RR_x}{R+R_x}\right] log_e \frac{E-V_b}{E-V} \quad (11)$$

Dividing equation (11) by (10) we obtain,

$$\frac{T_1}{T_x} = \frac{C_x + C_1}{C_x}, \text{ whence } C_x = C_1 \frac{T_x}{T_1 - T_x} \quad (12)$$

Cx is thus determined without any reference to its leakage resistance R_x.

Further, if the capacity is maintained, constant and R is varied, R_x may be determined under the conditions of experiment, and its variation with the charging voltage E may be easily investigated.

Examination of very High Resistances.

Fig. 2 shows diagrammatically the arrangement used for measuring a high resistance, such as the leakage resistance of a small condenser (resistances of 100 megohms or so can be easily measured by this method). A condenser C, of capacity usually of the order of one microfarad, is placed across the terminals of the lamp L, which is connected in series with the high resistance R and a battery of voltage sufficient to drive the lamp.

The condenser C charges up to V_c, and then discharges through the lamp: the presence of the external ionising agent ensures that discharge shall take place as soon as the voltage across the lamp has attained the critical value V_c. If E is the voltage of the battery, it is evident that the time required for the capacity C to charge up from zero potential to V_c volts, when a "flash" takes place, is given by,

$$T = CR.log_e \frac{E}{E-V_c} = 2{\cdot}302\,6.CR.log_{10} \frac{E}{E-V_c}$$

or, if the "flashes" occur at a rate suitable for counting, the condenser charges up and

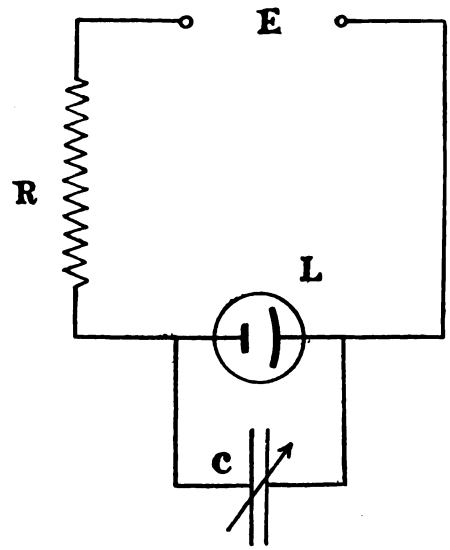

Fig. 2.

discharges between the voltages V_c and V_b, and we have for the time of "flash," the relation of equation (9).

Alternatively, if a standard high resistance of magnitude R_o, giving a time of "flash" T_o, is substituted for the unknown resistance, we have

$$\frac{T}{T_o} = \frac{R}{R_o}, \text{ whence } R = R_o \left(\frac{T}{T_o}\right) \quad (14)$$

By this method R may be determined for different values of the charging voltage E, and its variations determined.

A RE-UNION DINNER.

The Annual Re-Union Dinner for past and present Officers of No. 1 (T) Wireless School and Squadron, Royal Air Force, will be held at the Criterion Restaurant, Piccadilly Circus, W. (Jermyn Street entrance), at 7 for 7.30 p.m., on FRIDAY, 4th DECEMBER, 1925.

All Officers interested should communicate with the Hon. Secretary, MR. J. F. HERD, Ditton Corner, Datchet, Windsor, who will send full particulars as soon as they are available.

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Bedside Radio.

By A. G. Wood. **[R440**

AN experimenter's life is not a happy one these days. He has to carry out all his experiments between the hours of midnight and dawn, and as he usually has his daily duty to attend to as well, he seldom obtains much sleep or rest. The writer happens to fall under this heading, and has found through bitter experience that sitting up until about 3 o'clock every morning hardly gives one that "Kruschen feeling" necessary to carry out the day's work. He therefore set to work to minimise the strain as much as possible.

It is well known that to test out a circuit it is advisable to try it over long distances and under varying weather conditions in order to arrive at some conclusion. Also for testing various adjustments a few hours' work is not sufficient. The same remarks apply to the work upon which the writer is engaged—investigations relating to weather conditions and wireless. For this work it is necessary to be "on the air" every night from about midnight until 2 o'clock and the strain becomes acute after a week or two.

The writer conceived the idea of running the set from his bed, but immediately several difficulties presented themselves. Of course, it is practically essential to transfer the receiver to the bedside, but in the writer's case the bedroom adjoins the wireless room, so that it was not out of the question to knock a small hole through the connecting wall.

This was done and the aerial lead was taken through and attached to the set. Similarly low tension leads were run through and an earth attached to the gas main. It was found that the receiver worked quite as well under these conditions in spite of the longer aerial lead-in. The next question to be considered was how to change the aerial over from "receive" to "send," and to switch on the transmitter. Accordingly relays were installed, one at the aerial switch and one on the power board, the control leads being run into the bedroom and attached to a control board mounted up adjacent to the receiver.

Fig. 1 shows the original power switch installed on the switchboard. Under these conditions all worked well for a time until the power relay developed a habit of sticking down, with the result that the operator had to keep leaping out of bed after every transmission to switch off the power! This would never do, and accordingly steps were taken to improve matters. At the same time it was felt that losses were occurring at the aerial change-over switch, due to leakage, capacity, etc., and further improvements were looked for. Finally it was decided to erect a small receiving aerial in front of the house and to do away with the aerial change-over switch altogether. This was done with no loss in the efficiency of the receiver and a slight increase in that of the transmitter.

A special relay switch was constructed for the power board and resolved itself into a

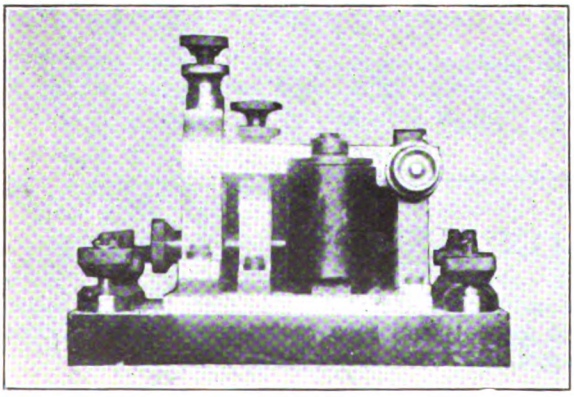

Fig. 1.

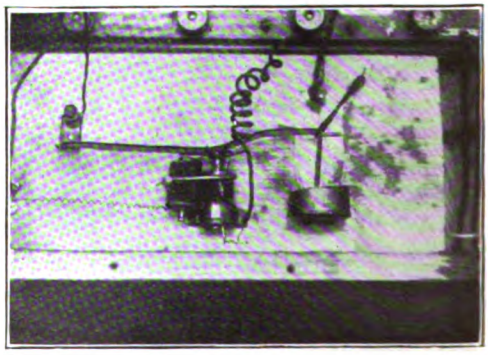

Fig. 2.

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mercury switch, breaking under oil (Fig. 2). This was much more satisfactory, except for the fact that the mercury and oil has to be renewed from time to time, as the two seem to form a sludge of some carbon compound. An attachment was made (not shown in the photo) for inserting a starting resistance before the full power was applied. This eliminated surges when the switch was thrown over. Fig. 3 explains this in detail. The blade of the switch is V-shaped and just before making contact with the mercury it engages with a small spring contact which has the effect of putting in a resistance of about 40 ohms for a fraction of a second before main contact is established. It might be mentioned here that this particular switch controls about 8 amps at 220 volts A.C. and seems to perform its duties in a very satisfactory manner. A small elastic band (or preferably a steel spring) returns the switch to the "off" position as soon as the control supply is taken off. Thus the arc produced at "break" is quite small.

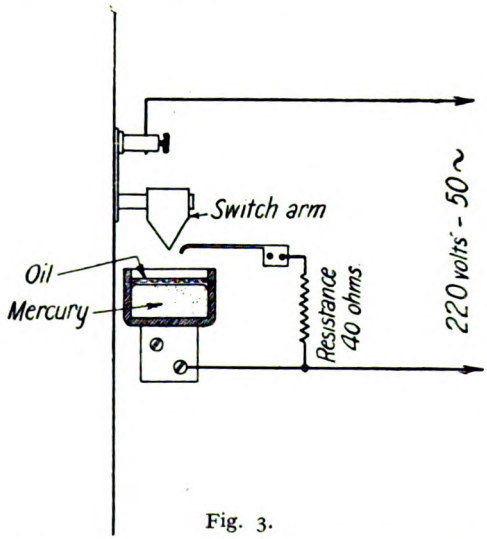

Fig. 3.

The control panel consists of a small cigar box, with a transmitting key and a Dewar switch. Fig. 4 shows the panel in question beside a portion of the receiver.

It might be thought that the receiving serial would appreciably affect the efficiency of the transmitter by absorption, but this is not the case. It is true that with 0.6 amp in the transmitting aerial it is possible to dim the filament of the receiving valve when the receiver is in tune and to obtain 0.1 amp in the receiving aerial but it must be remembered that the transmitter is working on a wave-

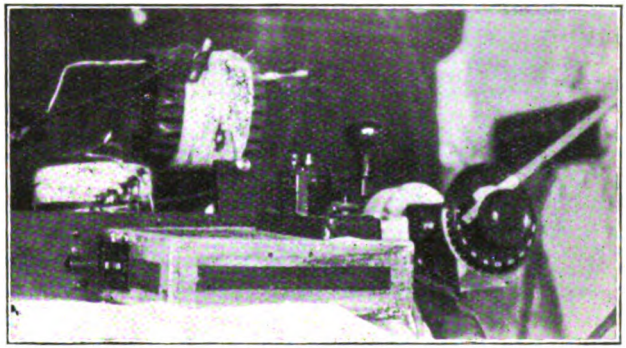

Fig. 4.

length above 90 metres, whereas all, or nearly all, the receiving is carried out on wavelengths below this, and under these conditions no absorption is noticeable.

The receiver is a modified Reinartz with an optional note magnifier and is all that can be desired. Using low loss coils, etc., very strong signals are obtainable from American and Canadian stations.

A word about the transmitter. It must be understood, of course, that in order to carry out this scheme, the transmitter must be reasonably safe to be left to its own devices, although any alteration which occurs when the set is running can generally be detected in the receiver. Apropos this remark, the writer had the exciting experience of having a small fire raging in the wireless room whilst he was sleeping the sleep of the just. A bad connection on the centre tap of the H.T. transformers caused a small arc to form, and set light to the waxed paper which was used for insulating layers of the secondary from one another. The transmitter was functioning (apparently) in a perfectly satisfactory manner and was duly switched off. The next morning when the writer entered the wireless room he found himself looking at the remains of what was once a perfectly sound H.T. transformer! However, if due precautions are taken, this should not occur more than once or twice during the course of the year!

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Fig. 5 shows the entire system and the method of keying. This method gives a spacing wave, the divergence of this from the marking wave being controlled by the

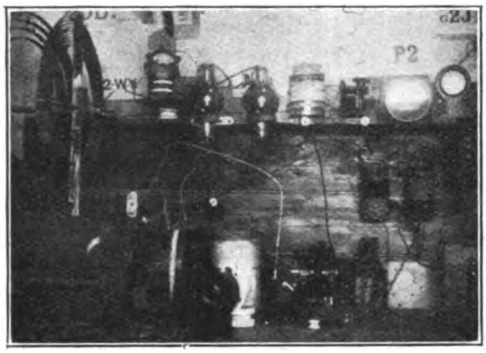

Fig. 6.

variable .001μF condenser across the resistance (200 ohms). The resistance is shorted out for the spacing wave which should be a little above the marking wave. This method has the effect of producing a perfectly steady wave which is essential for long distance work. There is no variation in H.T. voltage, etc., and the smoothing condensers remain charged to the same value the whole time.

The grid coil is not coupled to the plate coil and the set appears to give a purer wave when using this method. The valves employed are two Marconi T 50's in parallel and they work very well together. A coupled aerial circuit is used with a counterpoise of three wires 8 ft. high and 100 ft. long. The aerial is a four-wire cage 4 in. in diameter with a 40 ft. flat top and a 30 ft. lead-in, the height above ground being 70 ft. The wireless room is situated 40 ft. above the ground and immediately underneath the aerial.

Fig. 6 gives a general view of the transmitter.

In conclusion it may be stated that this station has worked over two dozen American and Canadian stations "from the bed." It is run jointly by the same operators as was last year's transatlantic station—G5RZ (which apparently earned a reputation for being unsuccessfnl in its object), but the location is now different. As an experiment a line was laid between the two locations and it was found possible to control the apparatus from the distant position as well as from the bedside.

In the words of a well-known electrical firm, "Rely on the Relay." The writer takes off his hat to the instrument which has most assuredly lengthened his life by a large number of years!

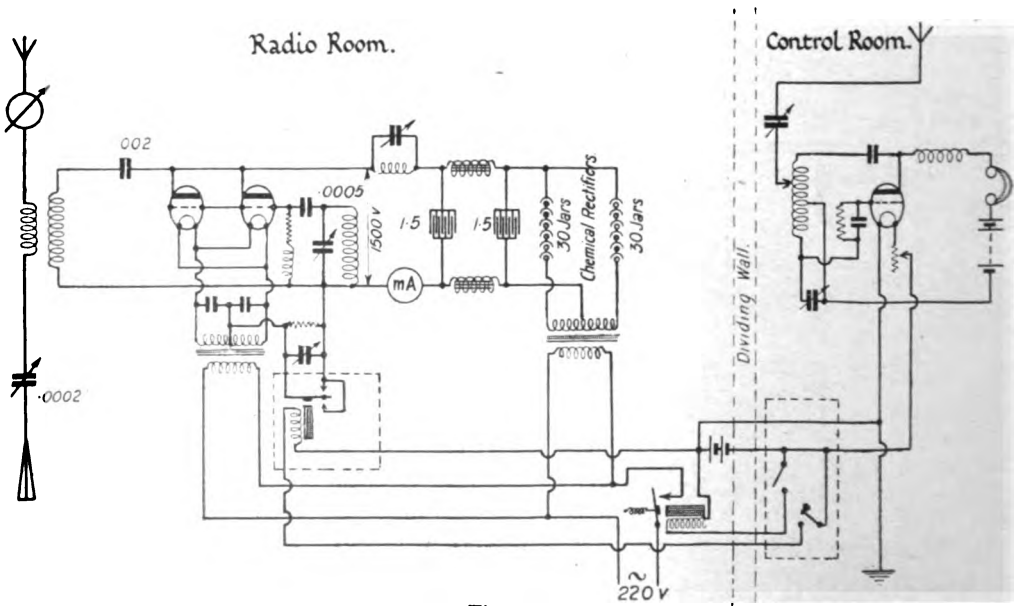

Fig. 5.

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Long-Distance Work.

By Hugh N. Ryan (5BV). [R545·009·2

THE most notable thing in this month's report is the way in which the great bulk of those interested have returned to the work after the summer "slack period." The change is not very apparent "on the air," as, anyway, we seldom hear our own stations on the 40-metre band where most of the work is now conducted; but it has been made apparent to me by the very great increase in the reports I have received for these columns. Most of my correspondents, I may add, have expressed satisfaction at the inclusion of foreign work in these reports, and a desire for more of it. This desire I am unable to satisfy to any extent this month; but I hope to do so soon. More countries are now sending me reports, but there are still some important exceptions, notably Spain, Italy and Finland, in each of which there are many stations working; perhaps a reader in each country will send me reports in future.

The general trend of work has changed little since last month, except that the Antipodes are occasionally worked in the evenings as well as in the mornings. The amount of this evening work would be very much greater but for the fact that broadcasting hours limit it to Sundays, and curtail it even on that day. (May I correct a prevalent idea among broadcast listeners, in case any of them read this, by stating that this is *not* due to our inability to receive 40-metre DX signals while broadcasting is on!)

At the time of writing, work with South Africa has not become general, but it has been accomplished at last, by G2LZ and O4Z. For some time before this event signals from O4Z had been coming in very well—almost nightly in fact—but again broadcasting usually prevented us from replying. Perhaps we shall be able to find some time outside broadcast hours when we can hear each other, but this has not yet been done. O4F of Johannesburg has not yet been heard here, but has heard G2LZ, G2SZ and G5BV.

Brazil, Argentina and Mexico are worked fairly regularly, but little work has yet been done with Chile, though ChlEG and Ch2LD are quite often heard here, the former being especially strong. Both have worked Britain, as has also Ch9TC.

We have yet to work the American 6th district, but several of us have recently had a sudden great increase in reports from that district, while their signals are more often heard here, so two-way work should soon be accomplished.

The higher-powered stations in London have been working much as usual, though I don't seem to hear a great deal of 5LF these days. All their signals are very weak in London and their phone, when they use it, usually unreadable, though OK at a distance.

2SZ has spent some time on 5 metres, his best DX being 5 miles (to 2VW). On 45 metres he has been heard in Russian Turkestan, and has worked two Chilians and a Mexican.

5BV has "heard and been heard by" both Chile and South Africa, without having worked either. 6QB is only on the upper waves at present, and has worked Spain and Germany on 4 and 3 watts respectively.

5YM has recently started working on 90 metres, and works most of Europe regularly with 10 watts.

6YK is working with a maximum power of 1.5 watts, with which he has reached as far as Italy. Experiments with T.V.T. generators and D.C. voltage raisers having both ended disastrously, this low power is likely to endure for a while.

Mr. Guy of Pinner and Messrs. Studley of Harrow send me very fine lists of stations logged, each including thirteen New Zealanders. 2QJ, of Gerrards Cross, is using 1.2 watts, with which he gets good ranges inall directions except through London.

6VP finds that his signals on 90 metres are always reported as stronger at 1 000 miles than at 50 miles, so that shorter waves have not a monopoly of this effect, though they exhibit it in a more marked degree.

A Mr. Drew (QRA pse, OM?) recently received fourteen Antipodes and South

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American stations in an hour in the early evening, a performance distinctly above the average.

5QV is making a determined attempt, by means of weekly schedules, to work the Canadian 4th district, but has had no luck so far. He has worked C3BQ's phone on one occasion. 2TO has not been working recently, but may soon be expected back on distinctly high power. 5SI, probably our best low-power station, has been trying to fulfil in truth the remark I recently made in jest, about his QRO to 5 watts for New Zealand. He has not yet quite succeeded, but he has done it with just under 12 watts, which is not a bad start.

2NB is working Z's on quite low power, and 5QT, in the same country, has worked Palestine at mid-day, also on low power.

6IZ is, I believe, the only station in Northern Scotland now working on 90 metres. He has been working for two months, during which time he has worked most of Europe. He hopes soon to be on 45 metres. 6MU (Belfast) has now worked both Australia and New Zealand, being the first Irish station to do so.

A number of amateurs have been keeping careful records with the object of trying to establish a connection between meteorological conditions and signal strength. Mr. Erith, of Sutton (Surrey) sends me an interesting graphical record covering September and part of October. 5YM is also keeping a very complete record of a similar nature. I know of a number of others doing the same, and they naturally want to get together with a view to pooling results. If any others in this position, who actually have some observations taken, will let me know, I shall be glad to put them in touch with each other.

Danish 7EC is still working as usual, and has been received in South Africa. 7ZM is just starting to work again. During the summer he made two trips from Copenhagen to Hull and back, keeping in touch with 7EC all the time.

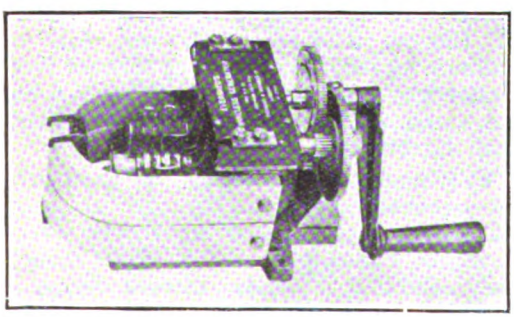
The Swedish ship *San Francisco* (SGC) left some time ago for South America, and several Swedish stations have been keeping him in touch with home. SMYY has worked Brazil almost nightly since May, and has also worked Argentine and New Zealand. SMZS has worked all over the world, but the owner is now away from home, and a second operator is in charge. The owner himself hopes to work on low power from his temporary QRA at Stockholm.

Chilian 9TC asks me to state that he is now using the call-sign CLAA for his work with RMA1. I hope that stations in all countries will send me reports of their work in future, and please remember that the post takes a few days to reach here. Reports should reach me by the 10th of each month, if possible.

Apparatus Tested. [R·009

The Evershed H.T. Generator.

Messrs. Evershed and Vignoles have submitted to us for test one of the hand-driven H.T. generators which they have now placed on the market for wireless purposes. The generator is of the type used in megger testing sets and has powerful permanent field magnets. We have given the generator trials under both station and field conditions, and, in general, have found it to be a useful and reliable piece of apparatus, particularly for portable work and under circumstances where other forms of H.T. supply are not available. It is suitable for 10-watt valve transmitters.



The Evershed hand generator.

The makers have wisely fitted a substantial handle with a four-inch stroke, allowing a powerful force to be applied to the gears provided that the generator is firmly bolted down to a solid bench. The handle operates the gears through a ratchet and pawl arrangement which prevents the armature from being rotated in the wrong direction. When no load is connected across the output terminals of the generator it turns easily and smoothly, showing that very little power is wasted as friction in the gears and bearings; a load taking, say, 15mA

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entails very much harder work in turning. The total gear ratio of 25 to 1 seems rather high and renders it somewhat difficult to maintain a steady speed of turning at full load. The trouble may, however, be attributable in part to the winding of the armature; the machine is rated to give 600 to 1 000 volts, and although it is easy enough to obtain these voltages on open circuit it is very hard work to maintain 500 volts across the terminals when a current is being supplied to the anode circuit of a transmitting valve. It should be mentioned here that our tests were carried out chiefly using valves of the L.S.5 type having a comparatively low impedance and taking a correspondingly large anode current; the low-impedance valve is rather coming into favour with amateur transmitters. Our tentative suggestion is that even for working in conjunction with valves of normal impedance the armature of the generator might be wound with rather fewer turns of wire so that a larger current could be obtained at lower voltages. We believe that this would not only permit turning at a slightly faster and steadier speed, but would actually allow more power to be delivered to the valve. It should be remembered that a nominal 10-watt transmitting set often has a choke control valve for telephony purposes, so that a total H.T. power of at least 20 watts may be required.

The commutator of the Evershed generator is worthy of note. It comprises four two-part commutators and four pairs of carbon brushes connected in some peculiar way which we could not investigate without dissecting the machine. The system of commutation is most effective in reducing ripple; without any smoothing device at all we have done some quite good telephony work, the commutator ripple being quite small and not interfering with the speech to any appreciable extent. With a condenser of 0.5μF across the generator the ripple became negligible and with the addition of a smoothing choke and a second condenser of 1.0μF absolutely no ripple was detectable at all. At full load there is slight sparking at the commutator brushes, but this does not appear to have any harmful effect.

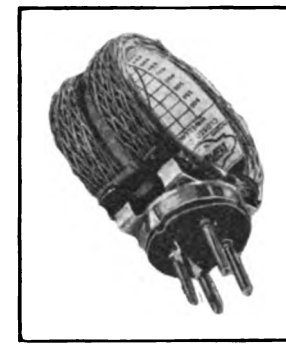
The generator is solidly constructed and there is very little that can go wrong. The armature windings are completely encased. For a cog-geared mechanism we consider it very silent-running. It is important to mention that the makers will also supply the generator with a driving pulley instead of the hand gear should it be desired to use a power drive.

The price of the hand-driven model is £13, and that of the power-driven model is £11.

Honeycomb High-Frequency Transformers.

The Igranic Electric Co., Ltd., of 149, Queen Victoria Street, E.C., are now making a series of high frequency transformers wound on the well-known honeycomb system as used for their inductance coils.

In each case the windings (primary and secondary) appear to be exactly similar in size and form, and are spaced by about ¼ in. They are fixed side by side and mounted similarly to an ordinary plug-in inductance, except that the base is circular and is fitted with a standard 4-pin plug, thus enabling the component to be plugged into an ordinary valve-holder.



The "Igranic" honeycomb H.F. transformer.

Incidentally, the plugs are mounted so that the transformers are inclined at an angle when the holders have the sockets corresponding to the grid and anode of a valve arranged in a line. This has the effect of reducing the mutual coupling between two or more transformers if mounted close together, which is a good point.

The transformers are made in four sizes, and we confined our tests to the smallest, which is stated to have a wave-length range of 288 to 538 metres when the secondary winding is tuned by a .000 5μF variable condenser in parallel. Further, since both windings appeared to be similar, we measured the inductance of one only, and found it to be 150μH, which corresponds roughly to an ordinary 50-turn coil. The self-capacity of this winding was 33$\mu\mu$F.

The coupling coefficient between primary and secondary was found to be on the low side, namely, 38 per cent. This is due to the rather large spacing between the two coils. We are of the opinion that in the case of the larger sizes the coupling coefficient would improve, because while the spacing between the coils remains the same, the coils themselves are much deeper. In fact, it is fairly safe to say that the coefficient would become about 60 per cent.

In conclusion, though these transformers are no doubt quite efficient components, we see no reason why a step-up ratio between primary and secondary should not have been introduced with a considerable increase in efficiency and without any adverse effects coming into play.

The prices range from 8s. to 12s. 6d. each.

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For the Esperantists.

Distordado. [R800

Oni nun diskutas la necesaĵojn por perfekta ricevado pere de transformatore-kuplitaj aparatoj, kune kun kelke da utilaj praktikaj konsiletoj.

PARTO IV.

MALLONGIGOJ: A.F., Alta Frekvenco; M.F., Malalta Frekvenco; A.T., Alta Tensio; M.T., Malalta Tensio; K.K., Kontinua Kurento; A.K., Alterna Kurento.

LA ELEKTO DE TRANSFORMATOROJ.

EN la lasta parto ni esprimis nian opinion, ke nunmomente la ŝok aŭ rezistanc-kuplita amplifikatoro ne havas veran avantaĝon por kompensi sian malefikecon. Ni nun pritraktos detale la transformatoran kuplecon, kaj unue konsideros la necesaĵojn, laŭ nia nuna vidpunkto (koncerne la kuplo mem) pri la desegno de transformatore kuplitaj aparatoj.

La tri punktoj, kiuj tuj sin montras, estas: (1) la proporcio de la transformatoro; (2) ĝia desegno; (3) iaj akcesoraĵoj ekster la transformatoro uzataj por helpi eviti la distordon. Ni antaŭsupozas ke, per ĝusta elekto de valvoj kaj zorga aranĝo de voltkvantoj, ni jam forigis valvdistordon.

Nun, pri la proporcio. Estas strange ke, se oni povus fabriki transformatoron teorie perfektan, la proporcio ne estus grava rilate al distordo. Sed unu el la ĉefaj efikoj de neperfekteco naskiĝas pro la mem-kapacito de la sekundaria vindaĵo, kiu donas al la transformatoro naturan frekvencon propran, kun rezulto, ke frekvencoj apud ĉi tiu troe grandiĝas. La uzo de alta proporcio plifortigas tiun ĉi efikon, kaj samtempe ŝanĝas la naturan frekvencon. Generale, per bonaj transformatoroj, oni malmulte eraros, uzante proporciojn laŭjene:—

Post valvo, tipo A.F., de anoda impedanco 25 000 omoj, 1 : 3; post valvo "ĝenerala," aŭ tipo 625b, de anoda impedanco, ĉirkaŭ 20 000 omoj, 1 : 3½ aŭ 1 : 4; post valvo, tipo M.F., de anoda impedanco, ekzemple, 15 000 omoj, 1 : 4 aŭ 1 : 5; post altpotenca valvo, de 5 000 ĝis 10 000 omoj, 1 : 5 aŭ 1 : 6.

Ser ial estas necese uzi transformatoron netrebonan, oni elektu proporcion iom malpi altan. Kontraŭe, se oni elektos transformatoron bonegan, oni povos uzi proporcion iom pli altan.

Rilate al la ĝenerala desegnado. Ni unue konstatu, ke ni celas doni konsilon pri *elekto* de transformatoroj. Notoj pri desegno de transformatoro por fabrikado estus multe pli komplikitaj, ĉar la desegno de M.F. intervalva transformatoro estas unu el la plej malfacilaj problemoj de la radio-industrio. Parolante ĝenerale, transformatoroj nuntempe vendataj suferas pro malsufiĉo de fero. Do, se oni bezonas bonan transformatoron, oni elektu tiun kun plej granda koro; la plej bonaj havas koron proksimume 2.5 c/m. × 2.5 c/m. en la meza membro. Ankaŭ, la koraj lamenaĵoj devus esti maldikaj.

Estas avantaĝo aranĝi vindaĵon sekcie, kvankam tio en si ne estas sufiĉa por bona transformatoro. Se eble, oni informiĝu pri la ĝusta nombro da vindaĵoj. Sekundario de 20 000 vindaĵoj (ĉirkaŭ granda koro) estas taŭga, la primario estante ŝanĝita por doni la ĝustan proporcion.

DIFEKTOJ EVITENDAJ.

Provante transformatorojn, certiĝu ke ne estas valva distordo, kaj tiam serĉu difektojn. La plej oftaj estas:—

(*a*) *Akreco.*—Raŭka sonado, kune kun troa emfazo je la altaj tonoj—ordinare pro tro malgranda koro. Kelkfoje transformatoro estos akra je la lasta ŝtupo, kvankam bonega je la antaŭaj. Tion kaŭzas pligranda K.K. tra la primario de la lasta ŝtupo, kiu troŝarĝas la koron.

(*b*) *Resonanco.*—Ekstra grandiĝo de frekvencoj en unu aparta regiono; tre rilatas al sekvanta difekto.

(*c*) *Malbona ekvilibro.*—Konstanta pliiĝo de emfazo, dum la tono plialtiĝas, aŭ eble dum ĝi malplialtiĝas. Efektive resonanco ĉe unu fino de la gamo. Ambaŭ ĉi tiuj ofte

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estas parte forigeblaj laŭ ĉi-malsupre, sed oni zorgu ke, kiam oni faras tion, la sekvanta difekto ne enkondukiĝos.

(*d*) *Fortranĉo.*—La forteco falas rapide ĉe unu fino de la gamo. Vere bona transformatoro funkcios bone de ekzemple 200 ĝis 5 000 cikloj, sed kelkokaze ĉio sub 1 000 parte perdiĝas. Aŭskultu atente al la fortepiana baso, trombono, kaj la basa vjolo, por la malalta fino, kaj al la altaj tonoj de la violono kaj pikolo, por la alta fino, kaj notu, ĉu ili envenas je plena forteco.

Oni devas, kompreneble, memori, ke ofte kelke da difektoj kunestas, sed akra orelo baldaŭ povos apartigi ilin.

PLIBONIGOJ.

Trie, venas la demando, kiel plibonigi la funkcion de neperfekta transformatoro. La plej konataj metodoj estas la uzo de alta rezistanco aŭ fiksa kondensatoro trans la vindaĵoj, kaj ili estas ofte uzataj. Oni devus kompreni, ke la efiko atingita per ŝunto trans la primario havas definitivan rilaton kun tiu atingita per ŝunto trans la sekundario. Se s estas la volvaĵa proporcio, tial la meto de ŝunta rezistanco aŭ kondensatoro trans la sekundario havos efikon laŭ grado s^2 de la sama kondensatoro trans la primario. Ankaŭ, la efiko pligrandiĝas laŭ la pligrandiĝo de la kondensatoro, sed pligrandiĝas dum la rezistanco fariĝas *malpligranda*. Tial, kun transformatoro, kies proporcio estas 4 : 1, kondensatoro .0001 trans la sekundario havas saman efikon (por malaltaj frekvencoj) kiel .0016 trans la primario, kaj 100 000-oma rezistanco trans la primario estas sama kiel 1½-megoma rezistanco trans la sekundario.

Nu, kiaj la efikoj? Ĝenerale ŝunta rezistanco iom malfortigas ĉiujn signalojn, sed aparte emas ebenigi ian neegalecon ekzistantan pro resonanco kaj malbona ekvilibro. Tia rezistanco nemulte helpos forigi akrecon aŭ "fortranĉon."

Ŝunta rezistanco, kontraŭe, emas al resonanco, sed ordinare je malplialta tono, ol alie okazus. Ĝi tial estas utila por malpliigi la akrecon aŭ tiun specon de malbona ekvilibro, kiu troemfazas altajn tonojn, aŭ por malpliigi la fortranĉon je malaltaj frekvencoj. Sed, uzante ĝin, oni devas zorgi ne kaŭzi apartan resonancon malaltan aŭ fortranĉon de altaj tonoj.

Ĉe transformatoro ne ŝirmita en metalujo oni kelkafoje ricevas utilajn rezultojn, vindante fadenon proksimume dekfoje ĉirkaŭ la transformatoraj vidnaĵoj mem, ĉiu el la dek vindaĵoj tuŝante al alian. Tio ordinare helpas al la ebenigo de la resonanco.

Sed tiaj rimedoj estas vere artifikoj, kiuj ne povas kompensi kontraŭ malbonaj transformatoroj; oni preskaŭ ĉiam malsukcesas, per ili, havigi vere kontentigajn rezultojn, por kio oni devas dependi je vere bonaj transformatoroj. Tiaj transformatoroj apenaŭ bezonas tiajn rimedojn, kaj oni devas eĉ observi, ke la ŝunta kondensatoro uzata en la detektora anoda cirkvito ne estas tro granda (.0001 estas sufiĉe granda), aŭ ĝi eble havos efikon.

STABILECO INTERNE DE LA APARATO.

Kelkaj punktoj estas prikonsiderindaj ĉe aparatoj kun kelke da ŝtupoj de M.F.'a amplifado. La plej evidenta estas la demando pri stabileco. Ne malofte okazas, ke eksperimenta aparato komencas persistajn oscilojn. Ili konsistas el du specoj. Unu speco havas nenian rilaton kun la amplifikatoro mem. Ĝi naskiĝas kiam kelkaj el la valvoj estas mikrofonemaj. Tiuokaze, se la laŭtparolilo estas sur loko, de kie ĝi povas ĵeti al la valvoj laŭtan bruon, ili eble amplifos la bruon mikrofone, kaj la tuta aparato baldaŭ bruegos. Tio estas kuracebla, se oni uzos malpli sentemajn valvojn, kaj formovos la laŭtparolilon.

Pli malfacila afero estas la kuraco de persista mem-oscilo, kaŭze de vera M.F'a reakcio interne de l'aparato. Oni ofte diras, ke ĝin kaŭzas la valv-kapacito, sed estas tre dube, ĉu tio vere okazas je malaltaj frekvencoj. Ĝi preskaŭ ĉiam estas kaŭze de hazarda kuplo *ekster* la valvoj.

Oni eble ne unue komprenos, ke la A.T'a baterio estas fonto de kuplo se (kiel ofte okazas) ĝi posedas iom altan rezistecon. Granda kondensatoro—ekzemple, 1 μF—devus esti metita trans ĉiu pozitiva ŝtopilo (se estas pli ol unu) kaj la negativa fino. Oni ofte nuntempe uzas savan rezistancon ĉe unu el la kondukiloj, aŭ interne de ŝtopilo aŭ aparte. Ankaŭ, kompreneble, estas la demando pri senpera magneta kuplo de unu transformatoro al alia. Sirmitaj aŭ aliaj bonaj transformatoroj estas kelkfoje meteblaj tutapude sen ĝeno; sed kelkaj tipoj ne funkcias bone se la distanco inter ili estas pli ol 30 cm.

En nia sekvanta parto ni pritraktos la du restantajn punktojn, la laŭtparolilon kaj la detektoron.

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Letters of interest to experimenters are always welcome. In publishing such communications the Editors do not necessarily endorse any technical or general statements which they may contain.

"Wipe Out."

The Editor, E.W. & W.E..

SIR,—I noticed on p. 853 of the October issue of E.W. & W.E. an article entitled "Wipe Out." Whilst not criticising the subject matter of the article, I should like to state that, in my mind, the term "wipe out" has never been associated with the automatic synchronisation of valve oscillators.

The latter phenomenon is well known, but as far as I am aware, has no "slang" title, although in its application to telephony it has been christened the homodyne or "zero beat" method of reception.

I think the term "wipe out" has always been associated with the literal wiping out of signals on a receiver, when the amplitude of the local oscillations is increased to such an extent that the mean grid potential of the rectifying valve is sufficiently large in the negative direction to cut off the anode current of that valve. It is evident that this condition will give rise to a complete disappearance of all signals, whether these synchronise with the oscillator or not.

There are important differences between the two phenomena in question. First, to produce automatic synchronisation on "pulling-into-step" by the incoming signals, the local oscillator must be moderately weak, although tightly coupled to the receiving system. To produce "wipe-out," a powerful local oscillator is necessary, its actual magnitude depending upon the circuit and adjustments of the rectifier.

Secondly, in the synchronised condition, although no beat note will be heard, any modulation on the incoming carrier wave will be received perfectly; it is, indeed, the ordinary homodyne method of reception, and further, it can be carried out without the usual rectifying arrangements, as shown by Mr. Colebrook.

In the "wipe out" condition, neither beat note nor modulation can be received: the receiver is, in fact, "polarised," to quote another slang term in use among wireless engineers some years ago. The same effect can be produced by a powerful continuous wave transmitting station working in close proximity to the receiver.

R. L. SMITH ROSE.

National Physical Laboratory,
Teddington, Middlesex.

The Editor, E. W. & W.E.

SIR,—I am interested in the matter discussed on page 853 of the October issue, in which two trains of oscillation are present in a receiver. There is a phenomenon which takes place in this case which I have not seen mentioned anywhere, but which was a little surprising when noticed.

The receiver consisted of a Moullin voltmeter of the grid rectification type, with the normal anode current balanced out by the filament battery. The input was connected across an ordinary tuned aerial circuit, and when tuned to 2LO a current drop of 70 microamps was shown at resonance. A separate oscillator was arranged to give a reading of equal strength, and this was slowly tuned across 2LO's wave. An increase in the reading was noticed even before a note was heard in the phones, and this increased until, when near resonance and a low, audible note was being produced, the deflection was approximately double that with either oscillation alone.

When the oscillator was brought into step it was expected that the two trains of oscillations would add up to produce one of double strength, but instead the reading went back to zero, the two oscillations completely neutralising one another. The only indication was produced by 2LO's modulation, which, consisting of side bands of a different frequency, were not neutralised.

If the oscillations were of different strengths, the decrease in reading on falling into step was double the difference between the two.

The reason for the gradual increase in deflection as the two sets of oscillations are brought near resonance is obvious from a consideration of the expression for the sum of two sine waves of different frequency, but it is not clear why, when they fall into step, they should do so in opposite phases. Perhaps somebody would explain this matter.

MARCUS G. SCROGGIE, B.Sc.

19, St. Mildred's Road,
Lee, S.E.12.

An Esperanto Society.

The Editor, E.W. & W.E.

SIR,—For some time past your progressive paper has been in the habit of publishing articles in our language, and, in consequence, quite a number of your readers joined our circle last Friday.

As it is not generally known that we exist, and especially as we serve a very large area, I would be extremely obliged if you would publish this letter, feeling sure that a large number of your subscribers will welcome the information.

The New Cross & District Esperanto Circle.
W. H. MATTHEWS (*Hon. Sec.*).

Clyde Street, Deptford.

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The Supersonic Patent.

The Editor, E.W. & W.E.

SIR,—Our attention has been called to your article on "Supersonics" on page 800 of your issue for October.

From this we notice that it is your intention to give detailed designs of a supersonic set. In doing so, we would ask you to be good enough to make due acknowledgment of the fact that the basic patent covering the construction of wireless receiving sets employing the supersonic principle, namely British Patent No. 143,583, is the property of this company.

Any amateur wishing to construct a supersonic set should apply to us for a licence, accompanying his application with the royalty of 30s., on receipt of which a licence will be issued immediately.

We would like to mention that the royalty of 30s. is irrespective of the number of valves employed.

Western Electric Co., Ltd.
H. A. P. DISNEY (*Asst. Sec.*),

Connaught House,
63, Aldwych, London, W.C.2.

The "R.I." Transformer Curve.

The Editor, E.W. & W.E.

SIR,—I have read with interest the letter of your correspondent, E. A. Anson, and first of all, wish to state that it was anticipated before the publishing of the advertisement referred to that criticism similar to this would be forthcoming.

I agree with your correspondent that the perfect transformer would be the one which amplified, not only all frequencies equally, but amplified to the same degree, greatly varying input values of energy, at each frequency. Herein lies the difficulty and the factor which is not generally realised.

In the plotting of an amplification curve, some arbitrary and constant value of input current must be taken as the basis, and the curve obtained is only correct for the particular value of input energy used. In practice, however, the amplitude of the incoming energy may be hundreds of times greater at once frequency than another, and unless a series of curves is obtained for each value of input energy, it is a decidedly incomplete characteristic of the apparatus under test. Obviously, it is not possible to obtain a reliable series of amplification curves, covering the wide variations of input current. The N.P.L. calibration curves shown are only correct as far as they go, and are not necessarily indicative of the results which may be obtained in actual reproduction. When the input energy applied to a transformer is below a certain value, the amplification factor practically disappears, and as the smaller values are usually at comparatively high frequencies, forming the overtones and harmonics of cound, some means of compensation must be employed to maintain a more complete reproduction of all the different frequencies.

Your correspondent will, therefore, see that in general the "R.I." theory does not differ from his own, except that the "R.I." theory goes further, inasmuch as it takes into account the minute values of input energy for which it is not possible to obtain a reliable characteristic curve.

It should be appreciated that in order to obtain a high amplification factor of the lower frequencies, that is, in the vicinity of 200 per second, it is only a question of increasing the number of turns and consequent impedance of the windings. On the other hand, by using the larger number of turns, the effect of self capacity is unavoidably increased, and the amplification of very weak high frequencies decreases enormously.

A large number of experimental transformers are made and tested every year, and while some of them give what seem at first beautiful mellow tones at low musical frequencies, the overall reproduction leaves much to be desired.

I do not agree that the advertisement is misleading, and the "R.I." transformer stands on its merits according to the satisfaction to the user.

Radio Instruments, Ltd.,
WM. A. APPLETON (*Director*).

12, Hyde Street,
New Oxford Street, W.1.

A Standard Report Card.

The Editor, E.W. & W.E.

SIR,—I have read with interest the letters which have appeared in E.W. & W.E. *re* the standard report card, and would like to state that as a non-transmitter I agree fully with Mr. King, whose letter appeared in your September issue.

I have settled on a type of card, of which I enclose a specimen, as a result of a considerable number of changes, and feel that, for non-transmitters, it is quite a reasonably satisfactory article.

A. STEWART CLACY.

10, Melrose Avenue,
Reading.

A. S. Clacy
To Radio

10, Melrose Avenue,
Reading,
Berkshire,
ENGLAND.

UR SIGS HRD HR ON CLG
WKG

QSD. G.M.T. *QRH.* METRES.
QRK. R *QRB.* KILOMETRES
QRZ. *QSA.* *QRM.* *QRN.* *QSS.*

Receiver. HF. D. L.F

Aerial. *Cpse.* *Earth.* *Remarks.*
Wires Wires
Height Height
Length Length

PSE QSL BY CARD. 73s.

Aerials and Lightning.

The Editor, E.W. & W.E.

SIR,—A few instances have been reported during the past summer of wireless apparatus being destroyed by lightning, but considering the number of aerials now in use, the damage has been unexpectedly small. The extent to which aerials are affected by lightning discharge and the results likely to arise therefrom are questions of practical importance to all users of wireless apparatus, and an attempt is being made to collect information relative to actual cases in which aerials and apparatus have suffered in this way. I should be glad if I may use the publicity of your columns to ask anyone, and everyone, whose apparatus has been

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damaged, to forward full information to me at the address given below. The data particularly required are :—

(A) The date and time of the occurrence.

(B) The position and approximate dimensions of the aerial.

(C) The nature and position of the earth connection.

(D) A brief description of surroundings, *i.e.*, position of adjacent houses, trees, telephone wires, etc.

(E) Whether the aerial was directly earthed or whether either receiving or transmitting apparatus were in circuit.

(F) The fullest possible description of the incident and the nature of the damage done.

CECIL L. FORTESCUE.

City & Guilds Engineering College,
Exhibition Road, S.W.7.

Station News.

The Editor, E.W. & W.E.

SIR,—It may be of interest to you to note that the P.M.G. has granted me an artificial aerial transmitting licence, the call sign allotted to me being 2BLO.

J. A. A. NOTTAGE.

26, Manbey Street,
Water Lane, Stratford, E.15.

The Editor, E.W. & W.E.

SIR,—Will you please advise your readers that any QSL cards for South African transmitters may be addressed to c/o S.A. Radio Relay League, "Myrtle Grove," Irwell Street, Observatory, Cape Town.

J. S. STREETER.

The Editor, E.W. & W.E.

SIR,—Kindly note that from this date my call sign is G6TB. 10 watts maximum, 150/200 metres, 45 metres, 23 metres, C.W. and phone QRA as above.

No fixed schedule for general tests, but reports from amateurs logging occasional general test calls will be welcomed, and will be acknowledged in every case.

Am QSO with G5NJ on low power at fixed times.

The original call sign 5RL expired a long time ago, but has not yet been deleted from all the call books. Congratulations on the continued excellence of "E.W.," and best 73's.

JOHN A. SANG.

22, Stranmillis Gardens,
Belfast (Northern Ireland).

The Editor, E.W. & W.E.

SIR,—I believe that my QRA is unknown to a number of amateurs. I should be pleased if you could make this known in the next issue of your journal, also that I am making tests on 23, 45 and 90 metres, with a power of from 2 to 4 watts. All QSL cards acknowledged by return.

Wishing your journal every success.

F. COLSTON HARDWELL,
(British 2GY.)

91A, Temple Street,
Bristol, England.

The Editor, E.W. & W.E.

SIR,—I beg to inform you that the call sign 5JO has been allotted to me in place of my old one, 2ARY.

Transmissions will take place in a few weeks on 150-200 and also 440 metres. Reports will be very welcome, and will all be answered. Power, 10 watts.

LAWRENCE W. JONES.

50, King Street, Cambridge.

Proposed Institute of Radio Engineers.

The Editor, E.W. & W.E.

SIR,—I have read with astonishment the arguments advanced by Mr. H. Gambrell in his letter published in your October issue. I do not know what Mr. Gambrell means when he says "wireless has become a large family." If he refers to the family of broadcast listeners, I can well understand why they cannot be housed "under the roof of the I.E.E."

Wireless engineering embraces not only most phases of electrical engineering, but many branches of civil engineering as well. This is well known to any wireless engineer who has been entrusted with the erection of even a small powered wireless station. Why, therefore, should the labelling of a wireless engineer as a "chartered electrical engineer" falsify the status of the latter? It may "bring blushes to the cheeks of the purely wireless *man*," as Mr. Gambrell suggests, but not to the wireless engineer.

The second paragraph of Mr. Gambrell's letter seems to me inconsistent with the first. He outlines the training of a wireless engineer, which I find it difficult to differentiate from the training of an electrical engineer. In any case the proposed syllabus contains nothing which could "falsify the status of electrical engineering."

I have had 18 years' experience of wireless engineers and have been responsible for the selection of a number of men, and, so far as my experience goes, all the most successful men have developed from those having a sound University training in electrical engineering. True, as Mr. Gambrell states, may of these men commenced their wireless activities as amateurs, often while engaged in other branches of electrical work, but without their initial training they would never have reached the positions they hold to-day. As in many other vocations in life, it is often a mistake to specialise in a professional capacity too early.

I believe that the link between wireless and electrical engineering, which the I.E.E. has forged by the formation of the Wireless Section, is too valuable to be broken and will be productive of many new workers to the radio field, while catering for all the needs of the professional wireless engineer of to-day.

B. BINYON, O.B.E., M.A., M.I.E.E.

34, Norfolk Street,
Strand, W.C.2.

[While Major Binyon's statements are all perfectly correct, it would appear that he has not quite grasped the point of the controversy, which is the allegation that the I.E.E. does not properly serve the Wireless Engineer: the last two lines of his letter beg the whole question at issue.—ED., E.W. & W.E.]

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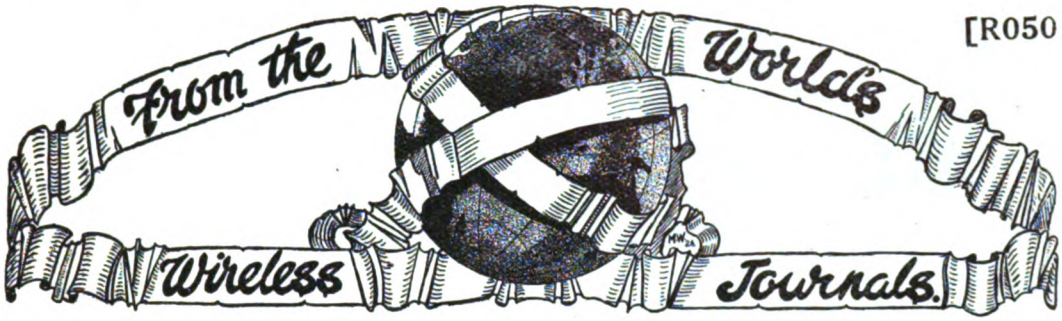
[R050



R.200.—MEASUREMENTS AND STANDARDS.

R240.—METHODE ZUR BESTIMMUNG DES ANTENNENWIDERSTANDES.—M. Osnos (*Zeitschr. f. Hochfrequenztechnik*, Vol. 26, No. 1).

Some methods of discussing aerial resistance are discussed. It is pointed out that the well-known method of coupling the aerial circuit to a source of oscillations and noting the aerial currents for various values of added resistance is not strictly accurate unless the mutual inductance between the source and the aerial circuit is taken into account. A method is described in which this mutual inductance is taken into account. Let R_a be the aerial resistance, i_c the current in the drive circuit, i_a the aerial current, M the mutual inductance and ω be 2π the frequency. Adjustments are made until the ratio $\frac{i_c}{i_a}$ is a minimum. Under this condition the aerial resistance is given by the relation: $R_a = \omega M \left(\frac{i_c}{i_a}\right)_{min.}$

Another method of measuring aerial resistance is described in which a loading inductance and a series condenser are included in the aerial circuit. Between some point on the loading inductance and another point somewhere in the aerial circuit on the other side of the series condenser the H.F. potential difference is a minimum. These two points are found by trial and the potential difference $E_{min.}$ between them is measured. Then, if the aerial current is i_a, the aerial resistance is given by:

$$R_a = \frac{E_{min.}}{i_a}$$

A modification is also described by means of which the aerial resistance may be determined by measurements made in an intermediate coupling circuit.

R269.—ELECTROSTATISCHE VOLTMETER UND GLIMMRÖHREN ZUR SPANNUNGSMESSUNG IN HOCHFREQUENZ.—A. Palm (*Zeitschr. f. Hochfrequenztechnik*, Vol. 26, No. 1).

There is not much choice in the matter of instruments for measuring high-frequency potentials, the electrostatic type being about the only available type. This article gives some constructional details of electrostatic voltmeters developed by the firm of Hartmann and Braun. These are virtually quadrant electrometers fitted with pointer and scale. For low voltages (5-150) the multi-cellular construction is used to increase the sensitivity. A most ingenious method of measuring H.F. voltages, and one which should commend itself to the amateur on account of its simplicity, is described. A neon discharge lamp of special construction is employed which starts to glow at a definite voltage (113 volts A.C. or 160 volts D.C.) independently of the frequency. This flashing voltage must first be determined by using a source of known E.M.F. at any convenient frequency. Two condensers, one fixed and the other variable, are shunted in series across the source whose E.M.F. is to be measured. The neon tube is connected across one of the condensers and the one which is variable is adjusted until the tube just glows. We the known the voltage across one of the condensers and by calculation from their relative capacities we can easily arrive at the E.M.F. of the source.

R271.—NOUVELLE CONTRIBUTION À L'ETUDE DE LA PROPAGATION DES ONDES.—M. Lardry (*Onde Elec.*, Sept., 1925.)

An article giving results of some signal strength measurements on wave-lengths of 450 metres, 200 metres, and 115 metres. Shunted telephones were used, this method allowing rapid readings to be made and giving curves consistent with those obtained by means of an oscillograph. The transmitting stations upon which the measurements were made were situated 180 kilometres from the receiver.

A number of fading curves are shown which were taken in various months of the year. The writer points out that statements to the effect that fading is absent on short wave-lengths (115 metres and below) are quite false. Variations in wave-length as well as intensity of signals were observed but it was found that these two types of variation were independent of each other.

R300.—APPARATUS AND EQUIPMENT.

R344.4.—SUR LES HARMONIQUES DES OSCILLATEURS À ONDES TRÈS COURTES.—C. Gutton and E. Pierret (*Onde Elec.*, Sept., 1925).

Some observations are described which were made upon the harmonics of the oscillations produced by valves generating on wave-lengths of the order of 2 metres with object of obtaining much shorter wave-length oscillations. With a one-valve oscillator it was found that the strongest harmonics were produced when anything was done which increased the stability of the oscillations, such, for instance, as increasing the coupling between grid and anode by bringing their respective leads closer together. With the two-valve symmetrical oscillator of Mesny strong harmonics to the seventh (47 cms.) were obtained when the symmetry was upset by displacing the anode connection somewhat. Another two-valve oscillator with reversed coupling was tried. This had a fundamental of 176 cms. and gave a number of detectable harmonics. The second was the strongest, but the fifth on 35 cms. could be measured with the aid of a very sensitive thermo-electric couple.

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R387.1.—THE SHIELDING OF ELECTRIC AND MAGNETIC FIELDS.—J. H. Morecroft and A. Turner (*Proc. I.R.E.*, Aug., 1925).

An experimental investigation of the shielding of electric and magnetic fields is reported for both constant and changing fields. The effect of using iron shells, or sheets, for shielding against the fields of permanent magnets, as well as those set up by electric currents, is considered; the best form for the iron sheets is deduced and an expression for the measure of the shielding action is suggested.

The reason for the leakage of electric and magnetic fields is shown to be due to the differences of magnetic or electric potentials in the circuit in which the fluxes are being set up; several cases are cited in which no external fields are set up, as the circuits exhibit no differences in potential. An expression for the shielding effect of a short-circuited coil is deduced and experimental verification is offered for frequencies between 10^2 and 10^6 cycles per second.

Finally the shielding effect of metal sheets against changing magnetic fields is analysed and experimental results are given to show how the action depends upon the characteristics of the material of which the shielding plate is made, its thickness, and upon the frequency used. The effect of slits in the metal sheet is indicated.

Amateur DX in South America.

By Ch9TC (Los Andes, Chile). **[R545·009·2**

I BELIEVE a note on the present position in South America will be of interest to British readers; of course, there are relatively few stations working at present, but results have been excellent.

Argentine.—CB8 has now worked four continents and been heard in five (unless he has found any more lately). His nightly "family press" to his son in Birmingham is, of course, familiar to British stations. Other Argentine stations have worked New Zealand and U.S.A., but CB8 rather eclipses everyone else.

Chile.—New Zealand has been worked by two of our stations and U.S.A. by one (the writer's); calls were exchanged by the writer and G2NM.

Over 250 U.S. stations have been logged at Ch9TC, but only two in Britain, and no others in Europe. It seems as though the tablelands of Brazil and the Andean range kill signals from the north-east, although, in the reverse direction, Ch9TC has been reported from Finland, Great Britain, Sweden and France, using 200 watts nominal. Australia and South Africa are QSA here.

Brazil.—Two-way communication was recently established between Bz1AB (Rio) and SMYY, and between 1AT (also at Rio) and U.S.A. These are the only DX achievements of which I have definite knowledge, but I believe signals were exchanged between Rio and Great Britain on at least one occasion.

Uruguay.—This is only just opening up on telegraphy, and as yet no DX has been recorded.

Bolivia.—A station at Oruro worked the writer months ago, but has not been heard since; I believe no DX is likely.

Local.—Chile, the Argentine, Brazil and Uruguay are steadily QSO, both in morse and telephony; this makes the route *via* Brazil to Europe worth trying whenever any traffic is held for other South American republics. Santiago de Chile has worked Montevideo and São Paulo with five watts nominal, and there are many higher power stations available, so that this route can be regarded as reasonably reliable.

The telegraphy amateur in these parts is a reasonable person, and little interference is caused with the broadcasts. There are exceptions, but at least 90 per cent. of such interference is due to amateur telephony stations, and it is in this direction that more stringent measures are likely.

Most apparatus is home-made. The standard receiver is the old Armstrong inductive-regenerative, with untuned primary—called locally the "Perry O. Briggs" from the U.S. amateur who recently re-popularised it in *Q.S.T.* Reinartz (original and latest), Reinartz-Weigant, and Paragon (plate-variometer) also have their adherents.

Transmitters are frequently Meissner; many stations are getting excellent results with inductively-coupled sets with untuned antenna, transmitting on a harmonic, *e.g.*, the five-watt Santiago station mentioned, Ch2LD, with 2 000 mile DX to its credit.

Wave-lengths range from 35 to 250 metres (in telegraphy: telephones go on up to 400 metres), but the majority are below 100 metres. Unfortunately we are just suffering from an attack of "40-metre" fever, and the QRM around that wave is bad—and increasing.

Ch9TC on 89 to 91 metres está à sus ordenes, senores!

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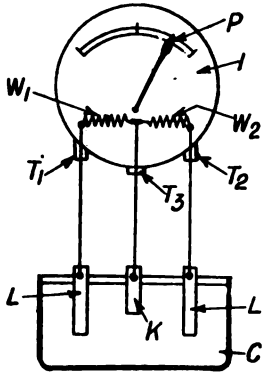
(The following notes are based on information supplied by Mr. Eric Potter, Patent Agent, Lonsdale Chambers, 27, Chancery Lane, W.C.2.)

[R008

THE CADMIUM BATTERY TESTER.

(Application date, 3rd April, 1924. No. 236,284.)

An interesting cell tester is described in the above British Patent specification by A. W. Rayworth. The method of operation is shown diagrammatically by the accompanying illustration, and it will be seen that the device consists essentially of a differentially wound voltmeter provided with two ordinary terminals and a third terminal connected to an auxiliary electrode designed to be introduced into the electrolyte of the cell to be tested.



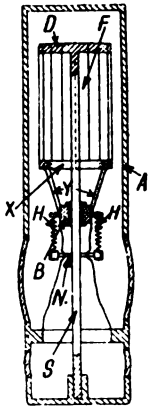
Thus the voltmeter comprises a centre zero instrument *I* provided with two windings *W*1 and *W*2 arranged differentially. The ends of the windings are connected to two terminals *T*1 and *T*2, while the centre tapping is taken to a third terminal *T*3. The cell to be tested is shown at *C*, and two elements *L*, to which the outer terminals *T*1 and *T*2 are connected, are also shown. The third terminal *T*3 is connected to an electrode *k*, preferably made of cadmium, which is introduced into the cell.

In operation the pointer *P* will indicate the true potential difference between the elements, and also the amount of charge remaining in the cell, *i.e.*, the pointer will indicate the net result of the potential difference between positive to cadmium and negative to cadmium. It is interesting to note that if the positive terminal of the voltmeter be connected to the positive element of the cell, during the time the cell is either on charge or discharge, the pointer will indicate the probable condition of the element. A similar method can be employed in the case of the negative element. We should imagine that the device would be very useful in practice, and we understand that it is already on the market.

FILAMENT CONSTRUCTION.

(Application date, 10th March, 1924. No. 235,295.)

A method of filament construction suitable for high power rectifying valves is described by H. J. Round in the above British Patent. The specification points out that when it is desired to obtain a large current and low internal resistance it is necessary to use a large filament close to the anode or grid. When this is done, difficulty has previously been experienced owing to the filament sagging due to the attraction from the anode, and when a number of filaments have been used in parallel similar difficulty has been experienced owing to magnetic effects. According to this invention these difficulties are overcome by constructing the filament in the form of a cage consisting of a meshwork or number of parallel wires, arranged in the following manner. Referring to the accompanying illustration it will be seen that the filament structure is supported from a disc *D* fitted to an upright stem *S*. The disc *D* carries the filament wires *F*, which are supported at the lower end by a spider *X*, providing supports *Y* fixed to a ring terminating in an insulated bush *B*. Springs *H* are placed between the ring and a support *N*, fixed to the stem *S*. Thus it will be seen that the spider supporting the filament is free to slide up and down the stem. The action of the springs can compensate for any expansion due to heating. The filament is shown inserted in a valve of the high power type containing an external anode *A*.



AN EXTRAORDINARY AMPLIFIER PATENT.

(Application date, 12th April, 1924. No. 236,993.)

British Patent No. 236,993, granted to S. W. Bligh and E. Ll. Crowe, has for its object the prevention of distortion by the use of iron core choke coils in the anode and grid circuits of the valve amplifier, and also to prevent the magnets becoming demagnetised or the windings burnt out, either, or all of which, it is stated, may happen when the high tension current is fed to the valves from the windings. So far as distortion is concerned, with the use of iron-cored chokes in the anode and grid circuits, this depends entirely upon the actual electrical constants, the use of which has been known for years. So far as the elimination of the steady anode current from the loud-speaker is concerned, this has also been known and it is

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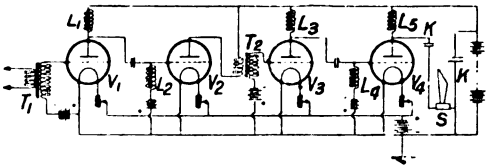
interesting to note that it can be shown mathematically that the distortion is inversely proportional to the steady magnetic flux, which is obviously increased by allowing the anode current to pass through the windings. Neither do we see how the magnets are likely to become demagnetised when a steady magnetising current normally flows through them, unless, of course, they are connected

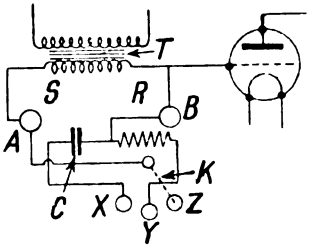


in the wrong direction, but this is not usual. Referring to the accompanying illustration, which shows one arrangement of the idea, it will be seen that the input to the valve $V1$ is an ordinary inter-valve transformer $T1$, this valve being coupled to the valve $V2$ by means of a choke $L1$ and a grid choke $L2$. $V2$ is coupled to $V3$ by a transformer $T2$, while the valve $V3$ is coupled to the valve $V4$ by a choke $L3$ and a grid choke $L4$. The loud-speaker S is connected through two condensers K across a choke $L5$ in the anode circuit. We confess that we do not see the novelty of the scheme, as we are of the opinion that all these devices have been known and used for some considerable time. Incidentally, the absence or presence of distortion depends entirely on the electrical constants of the coupling device, and this arrangement may easily produce far more distortion than a series of transformers. It is obviously dependent upon the design, and no details of this nature are given in the specification.

A TONE IMPROVER.

(*Application date, 19th March, 1924. No. 235,932.*)

C. H. Gardner, of the Midland Radiotelephone Manufacturers, Limited, claims a system of controlling or improving the tone of broadcast reproduction in the above British Patent. He claims in the invention the use of a number of impedances, such as condensers or resistances shunted across the secondary of a transformer, which is connected to the input of a low frequency amplifier valve. The specification contains actual constructional details of a device of this nature consisting of

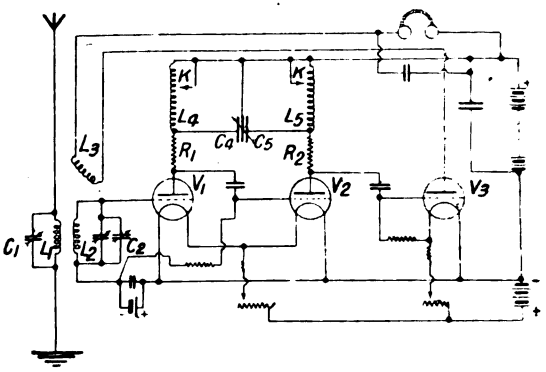


condensers and resistances arranged to be connected in circuits by means of a switch. One arrangement of the idea is shown in the illustration. It will be seen that the secondary S of a transformer T is connected between two terminals A and B. The terminal B is connected to the grid, while the terminal A should be shown connected to the filament and also the contact arm K of a radial switch, which is provided with contacts X Y and Z. When the arm is on the contact Z, the secondary is merely connected between the grid and the filament; when it is on the contact Y, a resistance R is shunted across it, while when it is on the contact X, a condenser C is shunted across it. Frankly, we do not see very much novelty in the idea as it has been customary to shunt a transformer with a resistance for many years, while the introduction of the condenser between the grid and filament of an amplifier valve is also well known. For example, readers will find the idea described in E.W. & W.E., Vol. 1, No. 1, October, 1923, page 26.

MULTI-STAGE HIGH-FREQUENCY AMPLIFICATION.

(*Application date, 12th March, 1924. No. 235,307.*)

A system of multi-stage radio-frequency amplification is claimed in British Patent No. 235,307 by Burndept, Limited, and C. F. Phillips. The invention relates essentially to a practical system of stabilising a number of similarly tuned circuits by the introduction of ohmic resistance. Referring to the accompanying illustration it will be seen that



a three-valve arrangement is shown, the valves $V1$ and $V2$ acting as radio-frequency amplifiers, while the valve $V3$ functions as a detector. The tuned aerial circuit $L1$ $C1$ is shown coupled to an input circuit $L2$ $C2$. A third coil $L3$ provides regeneration between the anode circuit of the detector valve and the input circuit of the first amplifier. The tuned circuits of the amplifier consist of $L4$ $C4$, $L5$ $C5$, a double condenser $C4$ $C5$ being shown. Greater wave-length change is obtained by variable contacts K. The system of radio-frequency coupling is therefore an ordinary tuned anode. However, between the tuned circuits and the anodes of each valve resistances $R1$ and $R2$ are included. It is pointed out in the specification that when a number of tuned circuits of this nature are arranged oscillation will occur owing to a regenerative effect being obtained by virtue of the inter-electrode capacities of the valve. In order to overcome this difficulty the resistances $R1$ and $R2$ are therefore inserted, this idea, of course, being well known for several years. The actual novelty of the invention lies in the construction of these resistances. They are wound with insulated wire over a brass or copper cylindrical former, which renders them non-

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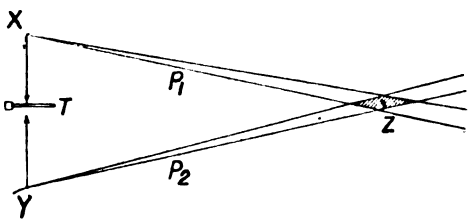
inductive, and at the same time act as a by-pass condenser to radio-frequency currents. It is stated that the resistance and capacity may be suitably proportioned by varying the size of the wire. We would point out, of course, that this system does not eliminate the transference of energy by inter-electrode capacities, owing to the by-passing effect of this condenser, which really exists across the resistance. The stabilisation, of course, is simply due to the introduction of resistances into the anode circuits of the valves.

INTENDED SECRET COMMUNICATION.

(*Application date, 9th April,* 1924. *No.* 236,647.)

A rather interesting system of secret communication is described by R. D. Bangay in British Patent No. 236,647, and is illustrated by the accompanying diagram. Referring to the illustration, it will be seen that the idea relates to a short wave beam transmission system, in which one transmitter is provided at *T*, alternative beam paths being shown at *P*1 and *P*2. The alternative paths are obtained by reflecting a beam at *X* and *Y* respectively, and



focusing the two beams on to the desired receiving point *Z*.

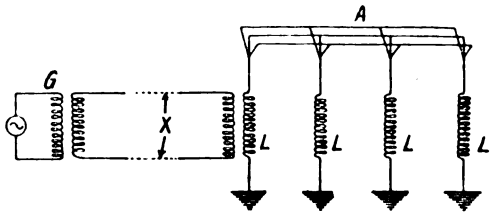
Secrecy can be obtained in a variety of ways. One method consists essentially in splitting up the dots and dashes, and sending the dots down one beam, and the dashes down the other. In the case of telephony one simple method is by the use of a double filter system, one filter rejecting all frequencies above, say, 1 000 cycles, and another rejecting all frequencies below, so that the resulting speech is split into two sections, each of which is sent down one of the beams.

Even this system, of course, would not give perfect secrecy. In the case of anyone being particularly desirous of obtaining the message, it would only be necessary to use two recording receivers, one arranged in each beam, the two records being arranged so that they blend together properly, in which case it would be possible to obtain the whole message.

A TRANSMISSION SYSTEM.

(*Convention date, U.S.A., 25th June,* 1923. *No.* 218,299.)

A system of transmission is described in the above British Patent by Marconi's Wireless Telegraph Company, Limited, and P. S. Carter. One object of the invention is to enable the radiating system to be placed at some distance from the generating system, the two being connected by a radio-frequency transmission line. Previously difficulty has been experienced owing to reflection taking place along the line, particularly on short waves, and this is overcome by the arrangement illustrated by the accompanying diagram. A multiple tuned aerial *A* is earthed through a series of inductances *L* and constitutes the radiating system. A source of oscillations is shown at *G*, and is situated at some distance from the aerial. The source of

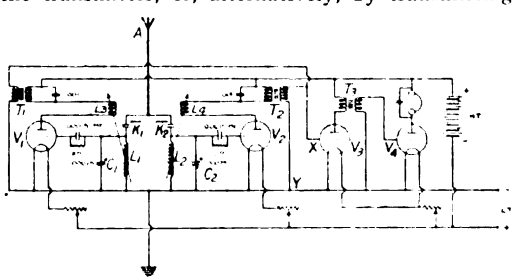


oscillations and the multiple tuned aerial are connected by a line *X*, and the losses in this line are a minimum when the transmission is at unity power factor, *i.e.*, when the current and voltage are in phase. In this condition no waves can be reflected back from the ends to interfere with the natural flow of energy into and out of the transmission line. This result is obtained by closing the end of the line with an impedance in such a manner that the effective impedance at the end of the line is equal to the surge impedance of the transmission line. It has been found in the case of a multiple tuned aerial that this condition is satisfied when the ratio of the total current flowing through the tuning inductance to the current flowing in the input inductance is equal to the square root of the ratio of the surge impedance of the line to the resistance of the aerial system. Another object and modification of the invention is to provide a system which gives directional transmission by utilising separate aerials fed from a single source from a number of transmission lines. The specification contains details and circuits of systems satisfying these conditions.

SECRET COMMUNICATION.

(*Application date, 6th March,* 1924. *No.* 235,275.)

A system of reception for use with secret methods of transmission is claimed by W. H. Fulford in the above British Patent, the accompanying illustration showing one form of receiver. It is stated in the specification that secret transmission is frequently obtained by periodically altering the frequency of the transmitter, or, alternatively, by transmitting



some speech frequencies at one radio frequency, while the others are transmitted at another radio frequency. The present invention consists in providing a receiver which will respond simultane-

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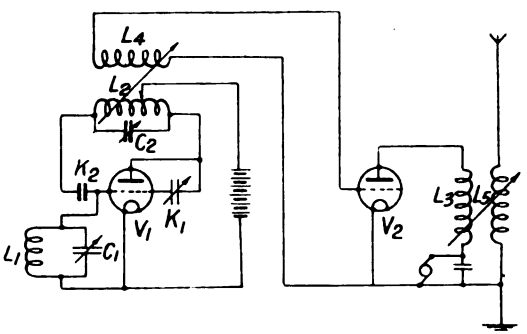
ously to the two different frequencies which are chosen. In the accompanying illustration it will be seen that two valve detectors $V1$ and $V2$ are employed. These are provided with tuned circuits $L1$ $C1$ and $L2$ $C2$, reaction coils $L3$ $L4$ being connected in the anode circuits and coupled to the respective grid coils. The anode circuits further contain the primary windings of transformers $T1$ and $T2$, the secondaries of which are connected at X and Y, between the grid and filament of the amplifying valve $V3$, which is further connected to another amplifying valve $V2$ by a transformer $T3$. A single aerial A is employed, and is coupled to the high potential end of the two tuned circuits, associated with the valves $V1$ and $V2$, through two condenser $K1$ and $K2$, each having a capacity of 0.000 01μF. This feature is the essential novelty of the invention, and in another modification these condensers can be included between the lower ends of the tuned circuits and the earth connection. It is claimed that a condenser of this capacity is sufficiently small to render the effect of the one tuned circuit upon the other comparatively negligible, and it is stated that approximately an equal amount of energy will be transferred from the aerial to the two tuned circuits on the two wave-lengths that are being employed by the transmitter. We should imagine that the scheme would work quite well.

ELECTROSTATIC MODULATION.

(*Application date, 25th April,* 1924. *No.* 237,025.)

A system of electrostatic modulation is described in the above British Patent by G. W. Hale, and the Radio Engineering Company, Limited. The general idea of the arrangement can be gathered by reference to the accompanying illustration. A valve $V1$ is provided with two tuned circuits, $L1$, $C1$ and $L2$, $C2$. The connection of the circuits $L2$, $C2$, to the anode, grid and filament of the valve is quite familiar, and constitutes the normal centre feed arrangement. Both $L2$, $C2$ and $L1$ $C1$, are tuned to the same frequency, this frequency being that of the transmission. The circuit $L1$, $C1$, replaces the ordinary grid leak. $L2$, $C2$ is coupled to a coil $L4$, which is connected between the grid and filament of a power amplifier valve $V2$, containing an anode coil $L3$, which is coupled to the

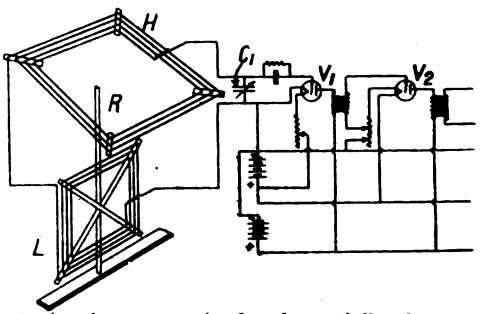


aerial coil $L5$. Between the anode and the grid of the valve $V1$ is connected a variable condenser $K1$ of similar capacity to the coupled condenser $K2$. It is stated that the regenerative coupling effect of the condenser $K1$ is equal and opposite to that of the condenser $K2$, and this condenser can be so arranged that normally no oscillations will be produced by the valve $V1$, whereas an unbalancing of the circuit will cause oscillations to be produced. This fact is utilised as a system of modulation, the sound waves either causing the condenser vanes to move directly, or through the medium of some electro-mechanical device. It is stated that the arrangement may be used as a quiescent system or that the condenser may be adjusted so that the valve is just oscillating. The specification is fairly detailed, and shows several modifications and arrangements of the idea.

UNI-DIRECTIONAL RECEPTION.

(*Application date, 7th July,* 1924. *No.* 235,407.)

A system of uni-directional reception is claimed by J. H. Herzog in British Patent No. 235,407. The invention consists in combining the effect of two frame aerials in such a manner, it is claimed,



that signals are received substantially from one direction only. The idea of the invention is illustrated by the accompanying diagram. Two valves $V1$ and $V2$ are shown, the valve $V1$ acting as an ordinary detector, and the valve $V2$ as an amplifier. The input of the valve $V1$ consists of the directional aerial system, which forms a closed circuit with the variable condenser $C1$. The aerial system comprises two loops or frames at right angles. The frame H is supported in a horizontal plane on a rod R while the frame L is supported in a vertical plane, and is capable of rotation. The two loops are connected in series, and form the input of the receiver. It is stated that the horizontal loop acts chiefly in the form of a capacity, and receives signals equally well in all directions, while the vertical loop L acts as an ordinary frame in a known manner: *i.e.*, maximum signal strength is obtained when the plane of the loop lies in the plane containing the transmitting and receiving station. The specification states that there is a peculiar relation or connection between the stationary coil and the vertical loop, whereby signals from one direction in which the loop lies will be blocked out, and only those from the opposite direction received. In other words, the device is similar to the ordinary cardoid system, which consists of a combination of a plain open aerial, and a frame, the superimposition of the two receiving diagrams giving the well-known cardoid. No receiving diagrams are actually shown, but we imagine that the scheme functions in this manner, although no definite suggestions are put forward.

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EXPERIMENTAL WIRELESS
& The WIRELESS ENGINEER

VOL. II. DECEMBER, 1925. No. 27.

Editorial Views.

Calibrations.

READERS are requested to note particularly that as from 1st December our Calibration Department will be closed down for a short period, as we are sending our standard wave-meter and condenser to be re-calibrated.

While we have no reason to suspect their accuracy, it is most desirable to have them tested at regular intervals, and this seems a suitable time. Some of our readers—especially those who have just completed their apparatus!—will probably disagree with our choice of a time; but in actual fact we note quite a strong "slump" at the moment, due to the fact that most experimenters got their apparatus into action in the summer or early autumn, ready for the winter's work: it is only the belated who are using the department now.

We hope that it will be possible to accept apparatus again in January, but in any case an announcement will be made in our next issue.

Patents.

Two patent matters of interest to amateurs have cropped up just recently, both involving the same point. The Standard Telephone Co. (ex-Western Electric) warn our readers that all supersonic receivers should pay royalty; Burndept Wireless, Ltd., point out that all tantalum rectifiers infringe their patents.

Several readers have written to us, stating that these claims cannot be maintained, on the ground that "anyone is entitled to use a patent for experimental purposes." The point is such an important one that we have asked a patent agent of our acquaintance to write an article giving the actual law on the subject. But in advance of this article we propose to give our own "layman's" view of the case for what it is worth.

Broadly speaking, we believe that one is only entitled to free use of a patent for research work on *the actual subject of* the patent. For example, one is probably entitled to build up a supersonic circuit for the express purpose of research into improved supersonic circuits. But if one wishes to do research on distortionless reception, or fading, etc., the mere fact that a "supersonic" is a useful instrument for the purpose does *not*, as far as we can make out, give one any right to use it. Even if it were the only possible receiver for the purpose, one would still be legally liable for infringement.

The same principle applies generally. One may build a patented article for the purpose of studying it and improving on it; but not as a tool in other research—much less as a means of getting musical entertainment.

In putting forward this expression of opinion, it must not be taken that we are necessarily supporting the line of action of either of the two firms, nor expressing any opinion as to the validity of these patents. As regards the latter point, any patent must

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be presumed valid until the contrary has been decided in court. As regards the former, it is true that the Marconi Co. has announced that it gives the amateur permission to use its patents for experimental work. An interesting point arises in that (we believe) both the Marconi Co. and the Standard Co. claim to hold the basic patent for the supersonic receiver; and we hear that they have arranged that either is entitled to license users of it. If this is so, can an amateur use it under the Marconi "free gift," or not?

Our Correspondents.

Just recently we have been regretfully compelled to refuse publication to one or two letters sent to us for that purpose in connection with some rather controversial subjects which have arisen in our "Correspondence" pages.

As the senders of these letters seemed at first puzzled at our action, thus making further explanatory letters necessary, it may be as well to explain our own views on the subject.

Our guiding principle is that the correspondence pages, like the remainder of E.W. & W.E., are published to give technical information to readers. Now, as a general rule, readers (as a whole) are not frightfully interested in the fact that Mr. Mugsworth, of Snorton-on-the-Flitch, disagrees with Professor Tallboy, of Brighton University, as to the influence of atmospheric conditions on fading. But they are interested in the question itself, and will welcome from Mr. Mugsworth any facts or serious reasoning tending either to confirm or disprove the Professor's theory.

In other words, it is useless for correspondents to send us letters such as the following:—

SIR,—

I am disgusted at your allowing Mr. ——'s letter to appear in E.W. & W.E.

Had he not been an advertiser you would not have printed it.

He is talking obvious nonsense.

Yours, etc.

(Which is the pith and essence of an actual letter received.)

As a matter of fact, we ourselves disagreed with the previous letter, but it stated a case for which some apparently sound arguments could be brought up. After reading the above criticism, we were inclined to view the original letter more favourably!

We do not wish to discourage correspondents: in fact, we believe in the great value of the free criticism of all published work; and we have no objection to hard hitting—but the weapon must be the club of reasoned argument, and not the jawbone of an ass.

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The Alignment Principle in Calibration.

By W. A. Barclay, M.A. **[R208·2**

Whereby the calculations incidental to calibration work are greatly simplified.

THE Principle of Alignment as an aid to computation is a comparatively recent mathematical development, the first work on the subject being published towards the close of the last century by M. d'Ocagne. The formula which it is desired to interpret numerically is illustrated by a diagram on which the variables are represented by numerically graduated scales (and, in more complicated cases, by a series of numbered curves). A straight line being applied in any position across the diagram, corresponding numerical values of the variables are found in alignment on their appropriate scales. Thus, when numerical values of certain of the variables are given, the related values of the others are immediately ascertained.

It will be seen that the Alignment Diagram constitutes a great advance on ordinary graphical processes. In the graphical solution of impedance relations, for example, a separate construction is necessary for the solution of each individual problem as it arises, the labour involved when several results are required being considerable. Using the alignment principle, on the other hand, once the diagram is constructed, it is available for all problems of similar type, whatever be the numerical magnitudes involved. Moreover, the same diagram may be used to find the value of any one of the variables concerned when the others are given, and thus provides the automatic solution of inverse as well as direct problems with equal facility.

The scope of the alignment principle in the numerical problems which arise in wireless work is very wide, and charts may be constructed to provide numerical solutions for such varied questions as impedance, equivalent series values for parallel combinations, damping and decrement, valve constants, etc. It is not, however, generally known that the new methods may be of the greatest service in the experimental determination of the constants of a piece of apparatus. This obtains by virtue of the extraordinary facility with which three, four, or even more variables can be shown, and their relations exhibited, on the plane surface of the diagram. This convenient method of representing the simultaneous variations of several variables is immediately applicable to problems of calibration, and in the present article two simple examples of its use in this connection alone will be discussed, to the exclusion meantime of its more important computational aspect.

Nothing in the nature of mathematical proof is here attempted, it being desired solely to describe the procedure in the special cases under discussion, and to demonstrate the advantages of the method. The general theory of the subject is of quite an elementary nature, and its uses in calculation, with instances of its application to various types of wireless formulæ, may be described in a future issue of E.W. & W.E. should sufficient interest render this desirable.

We shall now describe alignment methods of correlating inductances, capacities and wave-lengths, (A) neglecting resistance, and (B) including resistance as a fourth variable.

First, then, we consider the simple circuit of Fig. 1, in which an inductance is tuned by a capacity, there being no resistance present. Such conditions are approximately true of the "rejector" portion of the ordinary "tuned anode" circuit, where the D.C. resistance is generally very low, and where, of course, the coil is uninfluenced by magnetic coupling. We shall assume that the condenser used is of the semi-circular movable vane type, so that variation of capacity is proportional to change of scale reading except in the immediate vicinity of the values 0° and 180° on the scale. Under these conditions we have,

$$\lambda = k.\sqrt{LC}$$

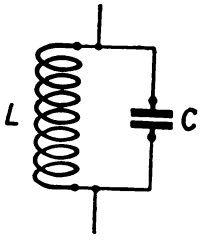

Fig. 1.

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where C includes the stray capacities of the circuit, and k is a constant.

It being desired to correlate the wave-lengths with the corresponding condenser settings for the different coils used in such a circuit, it is usual to plot condenser readings taken on the abscissa against ordinates giving the corresponding wave-lengths obtained with a particular coil. The different coils are thus represented by a series of curves on the diagram, and though by a simple device these curves may be transformed to straight lines, thus attaining a certain simplification, it is obvious that a number of inductances gravely complicates the diagram.

It is claimed for the alignment method that it is much simpler both in construction and use. Set out a scale of wave-lengths OA such that the distance from the zero o to any graduation is proportional to the *square* of the corresponding wave-length. (See Fig. 2.) This may be done to any desired scale, so that any selected band of wave-lengths may be conveniently represented. Next, draw a line BC parallel to OA and at any distance from it. Again, to any desired unit, take equal divisions on BC to represent condenser readings from 0° to 180°. It should be noted that the order of the graduations on BC is in the reverse sense from those on OA.

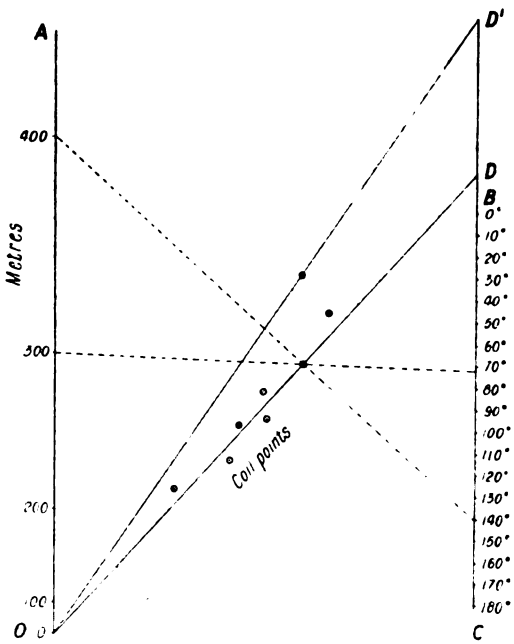

Fig. 2.

It will now be found that, for any given coil, all straight lines through corresponding values of wave-length and condenser setting will meet in a point, to which may be given the number of the coil in use. It will be seen that two such pairs of values are sufficient to determine the position of this inductance point, and that thus, from the known wave-lengths and condenser settings of but two stations, the point so found may in turn be used to determine the settings for other wave-lengths. Instead of a series of curves, we now have a series of points representing the inductances, to the great simplification of the diagram. Although, owing to the unavoidable presence of a minute resistance, the true position of these points is not exactly defined, it will be found in practice in ordinary tuned anode circuits that the triangle of error formed by the intersection of any three lines obtained by the use of one inductance is exceedingly small, and will not affect the use of the diagram. If the effect of resistance is large, however, as is the case in some other types of circuit, it will be necessary to adopt the procedure detailed below.

Meantime it is of interest to remark that, if the zero point O be joined to the point representing any coil, and is produced to meet the line BC, the resulting point D serves as a zero from which the total capacity in the circuit may be measured along the capacity scale DC. The portion DB between this zero and the commencement of the scale readings represents the amount of the stray capacity due to the coil and the wiring, while the graduated portion BC represents the variable capacity due to the condenser. An interesting measure of the efficiency or otherwise of our circuit is here afforded, as the length DB should obviously be as small as possible, Moreover, if our condenser is already calibrated in microfarads, we can obtain by proportion the numerical value of the actual capacity present at any time in the circuit. It is to be noted that the zero D from which this latter quantity is measured is not a fixed point, but varies slightly in position along BC according to the self-capacity of the coil in use. The graduations of the condenser

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scale-readings are, on the other hand, fixed. If the variable condenser has not already been calibrated, a fixed condenser of known value should now be placed across it, and the procedure repeated. This will entail a new position being found for the point which represents the coil, while the corresponding point of zero capacity D^1 is also found in the same manner as was D. The length DD^1 will now represent to the same scale the value of the capacity of the fixed condenser. The differences between the capacities at various scale-readings of the variable condenser may then be read off in proportion, while the total absolute capacity of the circuit is similarly reckoned proportionately from D^1 or D according as the fixed condenser is or is not included.

Incidentally this method provides an admirable means of comparing the values of small fixed condensers. The beautiful generality of the construction by which quite arbitrary units and distances may be used makes it a very powerful means of correlating the variables with which it deals.

It will be seen that, although we can distinguish between the capacities due to the variation of the condenser and those due to other causes, we cannot further analyse these latter into their constituents. Prominent among them are the minimum capacity of the variable condenser itself, the self-capacity of the coils, and that of the associated wiring. Though the fluctuations due to the changes of the coil capacities are shown on the diagram, it must be remembered that they are always associated with a certain fixed capacity of indeterminate amount. We cannot therefore proceed to an estimation of the actual magnitudes of these self-capacities, although we can observe the amounts of the differences between them.

It will also be noticed that no account has been taken of the numerical values of the inductances in use. While it is theoretically possible to derive them from the diagram of Fig. 2, it will be better, when these are desired, to resort to the procedure now to be described, which also takes account of the factor of resistance, and thus approximates to more usual conditions. The advantages of the alignment method in appropriating for each variable a particular form of geometrical representation here become strikingly apparent.

Our problem is now to correlate the condenser settings, wave-lengths and coil constants for the circuit of Fig. 3, in which the condenser, being assumed to possess no resistance itself, is placed across an inductance and resistance in series. Such a combination approximates closely to the conditions obtaining in most tuned circuits with plug-in coils, where the effective resistance of the circuit may be considered to act as a series load to the inductance, while the self-capacity of the coil is, in effect, added to the variable capacity placed across it. The combination, as is known, is resonant when

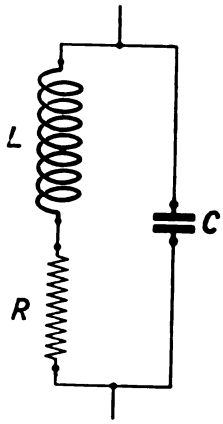

Fig. 3.

$$\omega = \sqrt{\frac{1}{LC} - \frac{R^2}{L^2}}$$

It is our intention to isolate geometrically each of the variables of this formula in order that the relation to each to the others may be easily and rapidly demonstrated. Owing to the small variations in the self-capacities of the coils, it will perhaps be better at first to draw out a separate diagram for each coil considered; a modification by which all coils may be represented on the same chart will be indicated later.

Taking ordinary Cartesian axes OX, OY (Fig. 4), we set out on OY to any convenient unit a scale of "Squares of Wave-lengths," similar to that of our first example. Upon OX, and measured linearly from O, is to appear our scale of capacity, part of which will be represented by the variable condenser readings. Unlike the capacity scale of the previous example, this scale of capacity values is always to be reckoned from the fixed point O, whereas before the absolute values of capacity were measured from a variable zero. We are thus confronted with the difficulty that we are unable, for the moment to assign the position on OX of the point from which the condenser readings are to start. If Q denote this point, the distance OQ represents the minimum capacity of the circuit

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with the condenser at zero. Though we cannot as yet fill in the actual condenser readings, we may, however, select the scale to which we desire these readings to appear. Having decided upon this, the actual

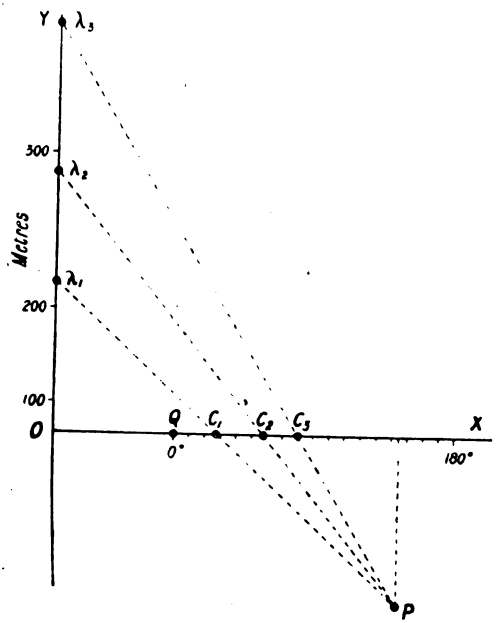

Fig. 4.

positions of the readings may be determined in the manner following.

The present calibration, involving as it does the extra variable of resistance, will necessitate a third correspondence between condenser setting and wave-length in addition to the two only which were required in the previous example. Suppose, then, that when using a certain coil of unknown inductance and resistance, which we may call (L,R), we obtain for the condenser readings r_1, r_2, r_3 the known wave-lengths λ_1, λ_2, λ_3. Let us assume further that $\lambda_3 > \lambda_2 > \lambda_1$. If, now, we can find one only of the points C_1, C_2, C_3 which are to represent r_1, r_2, r_3 to the desired scale on OX, the whole of the variable condenser graduations may be set out from this point, since the scale to which these are to appear has been already selected. Although the positions of C_1, C_2, C_3 are so far undetermined, the length of C_2C_3 is known in terms of the scale fixed upon for these markings. The ratio of this length to the distance OC_2 may now be obtained from the formula

$$\frac{C_2C_3}{OC_2} = \frac{(r_3-r_1)}{(r_2-r_1)} \cdot \frac{(\lambda^2{}_2-\lambda^2{}_1)}{(\lambda^2{}_3-\lambda^2{}_1)} \cdot \frac{\lambda^2{}_3}{\lambda^2{}_2} - 1$$

By this means the distance OC_2 is found, and the position of C_2, and hence of the whole condenser scale, is determined. The derivation of the above equation for the ratio of C_2C_3 to OC_2 need not here detain us, being obtained from theory to give the diagram the properties which will appear in the sequel. In order to dispense with the arithmetical work involved in using the formula, an Alignment Chart for its numerical solution is described in the Appendix.

We are thus in possession of our wave-length and capacity scales along OY and OX, and it should now be found that straight lines joining the points λ_1 to C_1, λ_2 to C_2, and λ_3 to C_3 will all meet in a common point P, situated below the axis OX, to which we may assign the distinguishing letters (L,R) of the coil in use. Using P as a pivot, a straight-edge will now intersect the wave-length and capacity scales in appropriate values for both these quantities for the particular inductance and resistance possessed by the coil. It may be of interest to note that a line through P perpendicular to OX will meet the scale of wave-lengths OY at infinity. The point at which this line meets OX may or may not lie within the limits of the condenser scale, and represents the limiting value of capacity beyond which the circuit will not tune. This, of course, corresponds to the fact that in the formula

$$\omega = \sqrt{\frac{1}{LC} - \frac{R^2}{L^2}}$$

when $C = L/R^2$, λ becomes infinite, while if $C > L/R^2$, the radical becomes imaginary. The abscissa of P, therefore, is proportional to the quantity L/R^2, a fact which will become otherwise apparent later. The distance from O to Q, the zero point of condenser readings, represents, of course to the same scale, the total stray capacity of the circuit, including that of the coil (L,R).

The above procedure may now be repeated for a different coil (L^1,R^1), care being taken to preserve the same scale for wave-lengths, and the same distances between similar graduations on the capacity scale. In

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general, the position of the condenser scale as a whole as found with the coil (L^1,R^1) will be slightly different from the position as obtained with the coil (L,R), due to the small variation in the self-capacities of the two coils. In Fig. 5, the new position of the zero point of the condenser readings is indicated by Q^1, the distance QQ^1 representing to the same scale of capacity the difference between the self-capacities of coils (L,R) and (L^1,R^1). Using the new position of the condenser scale on OX, a new point P^1 will be similarly found to represent the coil (L^1,R^1). In general, the co-ordinates of P^1 with respect to the axes OX, OY will differ from those of P, while by using P^1 as pivot, appropriate values of λ and C for the coil (L^1,R^1) will be found in alignment.

We may now proceed to compare the inductances and resistances of the two circuits which contain respectively the coils (L,R) and (L^1,R^1). Referring again to Fig. 5, let x and y represent the distances measured in any convenient units of the point P from the axes OY and OX respectively, neglecting the negative sense of y. Then it may be shown by the theory of alignment that the diagram possesses the following properties:—

(A) The inductance of the coil is always proportional to the quotient y/x.

(B) The resistance of the coil is always proportional to the quotient

$$\frac{\sqrt{y}}{x}$$

It follows, therefore, that if x^1 and y^1 denote the corresponding co-ordinates for the point P^1, the ratio of the inductances of the two coils (L,R) and $L^1,R^1)$ is given by

$$\frac{L}{L^1} = \frac{x^1y}{xy^1}$$

while the ratio of their resistances is given by

$$\frac{R}{R^1} = \frac{x^1}{x}\sqrt{\frac{y}{y^1}}$$

A very convenient and simple means of comparing the inductances and resistances of coils is thus presented to our use. The geometrical interpretation of the above equations is seen to be as follows:—

(A) All the points representing coils of the same inductance value lie on the same straight line through O, *i.e.*, the gradient of the line OP is a measure of the inductance.

(B) All the points representing coils of the same resistance value lie on the same parabola whose vortex is at O and to which OX is a tangent.

All numerical values of inductance and resistance are thus represented by a series of straight lines and parabolas respectively, the point corresponding to any particular coil being located at the intersection of the line and parabola which are appropriate to it.

In order conveniently to compare the numerical values attaching to the individual members of such a series of lines and curves, we may select any point on OX and draw through it a line parallel to OY. This line will meet the pencil of inductance lines in points whose distances from OX are proportional to the inductances concerned. The same line, or any other parallel to it, will similarly meet the resistance parabolas in points whose distances from OX are proportional to the squares of the resistances represented. A valuable means of comparing the numerical values of coil constants without elaborate apparatus is thus afforded. The experimenter will easily adapt the procedure to suit his own requirements, incorporating, wherever possible, known standards in his circuits, so that values in practical units may be obtained.

To simplify the above description a separate diagram has been drawn out for each coil to be represented. When it is remembered, however, that on each drawing the wave-lengths are represented on the same scale, while on each the distance between similar graduations on the condenser scale remains the same, it will be seen that this is not strictly necessary. The small variations of the condenser scale on OX do not, of course, affect the absolute values of total capacity as reckoned from O. Hence the change in position of the condenser markings as shown on the different diagrams does not affect the derivation of the inductance and resistance estimations. It thus appears that if a sliding scale be attached to the axis OX, upon which the

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condenser readings are inscribed, a single diagram will be achieved whereon can be exhibited at sight the relations obtaining between condenser settings and wavelengths for all desired coils. In practice, such a movable strip is easily held in the required position with the requisite security by closely fitting slits in the surface of the paper. The sliding scale can be adjusted in position to suit the self-capacity of the coil in use, the position of the zero point Q for each coil being determined once for all, and inscribed on the fixed axis OX. The points P for the coils themselves are found in the usual manner after the position of the condenser scale has been adjusted.

The total range of such adjustment of the condenser scale is very small, the self-capacities of ordinary plug-in coils being usually very small in comparison with the other capacities in the circuit, besides being themselves remarkably uniform in value. The introduction of the sliding scale to compensate for the minute variations arising from this source may seem in some cases a needless refinement. The size of the variable condenser used will be a chief factor in determining whether the use of the slide may be dispensed with without prejudice to accuracy.

In conclusion, it may be well to reiterate that the procedure detailed above is a particular case of a very general method. The rationale of the constructions which have been given, and their validity, will be self-evident to those acquainted with the theory of alignment diagrams for calculation. It was, indeed, while the writer was preparing some similar charts for computational purposes that the possibility of using the principle inversely for calibration work first occurred to him. If he has succeeded to any degree in arousing interest in a new and powerful weapon lying to the hand of the experimenter, his purpose has been achieved.

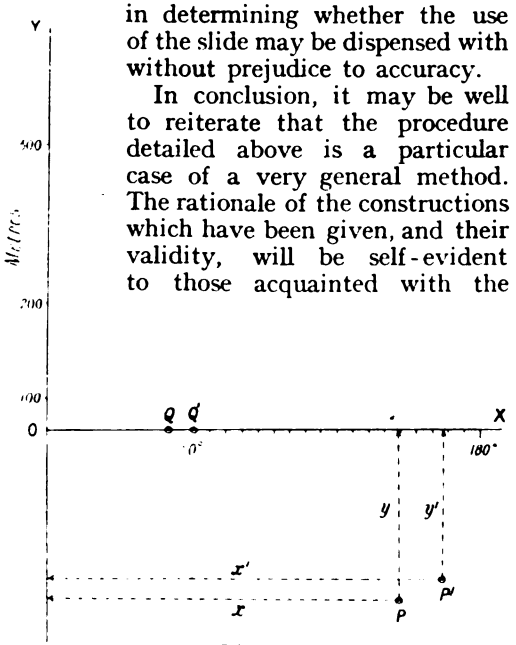

Fig. 5.

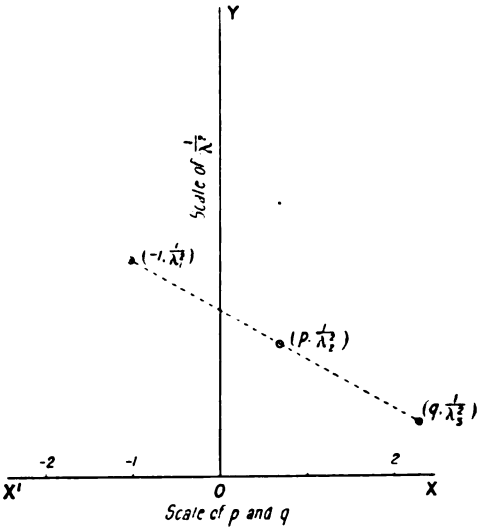

Fig. 6.

APPENDIX.

An alignment diagram for the solution of the equation

$$\frac{C_2C_3}{O\,C_2} = \frac{(r_3-r_1)}{(r_2-r_1)} \cdot \frac{(\lambda^2_2-\lambda^2_1)}{(\lambda^2_3-\lambda^2_1)} \cdot \frac{\lambda^2_3}{\lambda^2_2} - 1$$

is constructed as follows :—

Let us write,

$$\frac{C_2C_3}{O\,C_2} = p \text{ and } \frac{r_3-r_2}{r_2-r_1} = q.$$

Then, using Cartesian co-ordinates, the above relation is sufficiently expressed by the statement that the points $(-1, 1/\lambda_1^2)$ $(p, 1/\lambda_2^2)$ and $(q, 1/\lambda_3^2)$ are in alignment. (See Fig. 6.)

If now we replace the ordinary cartesian network by another in which, while retaining uniform graduations along OX to represent p and q, the graduations along OY are proportional to the inverse squares $1/\lambda^2$, we obtain a rectangular numbered network whereon the position of such points is obtained with extreme facility. Joining $(-1, 1/\lambda_1^2)$ to $(q, 1/\lambda_3^2)$ on this diagram with a straight-edge, we note where this line meets the ordinate line for λ_2. The abscissa of this point will then have the numerical value of p, the required ratio.

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Triode Valve Rectification. [R134

An attempt to show in simple form some of the lessons to be drawn from the paper on "Valve Rectification," by F. M. Colebrook, which is now appearing in E.W. & W.E.

As there may be some readers of E.W. & W.E. who find that Mr. Colebrook's important paper on the valve detector makes rather heavy demands on their attention, an attempt is made in the following notes to present a few of the conclusions in the simplest possible form, with especial reference to broadcast working.

The problem of finding out just what occurs in grid rectification is notoriously a very difficult one; but by attacking it from a novel point of view, Mr. Colebrook has succeeded in reducing it to a much more manageable form, and applying much of the analysis already carried out in his recent paper on rectification in general.[1]

The author begins his paper by giving the results of an investigation into the actual shape of the grid current curves of various values, and makes an interesting discovery which is of great service in simplifying the mathematical work. It appears that, within the usual working limits, the current follows a compound interest law: the addition of a given grid voltage *multiplies* the anode current by a certain amount. Hence there are, for any valve, two figures which can be given, which can be got mathematically from the grid current curve, and which express its rectifying power.

One of these, called *a* by Mr. Colebrook, depends mainly on the filament heat, anode voltage, etc.; the other, called *b*, depends on the design of the valve itself. Luckily the latter is the most influential as regards performance; so if we have it for any valve we can judge what to expect. Values of *b* in valves actually tested range from 3 to 7, the larger being the better.

If we know *b*, we can work out, from curves in the article itself, the probable performance of the valve under various conditions.

Unfortunately, even now the problem is not completely simple, involving the use of logs. But anyone with a fair knowledge of algebra can get, from section 7 of the article and the figures given, the steady voltage with a given leak, and the grid voltage drop produced by an incoming signal. It is interesting to note that in a typical case worked out, a signal voltage of .5 volt r.m.s. produced a fall in steady grid volts of .33 approx. It may be mentioned that the method of finding these results is fully checked by experimental results.

A method is also given of finding the H.F. resistance of the valve to input voltage—or rather, that part of it due to actual grid current: the already existing resistance due to capacity effects is not dealt with. The author shows that taking the lower end of the input circuit to a point of positive potential apparently increases the rectified output; but calls attention to the fact that this also increases the damping on the input circuit and may thus actually give worse results. His final conclusion is that a small positive voltage is likely to be advantageous.

The next part of the paper goes on to consider the rectification of modulated waves, and the author finds some exceptionally interesting facts on this. It has been generally believed (and the present writer pleads guilty also!) that the undoubted distortion which is found is due to the time taken to discharge the grid condenser *via* the leak. But it is shown by Mr. Colebrook that the most important trouble is not here at all.

The worst defect is that the actual efficiency of rectification depends on the modulation frequency, being greatest for low notes. On broadcast wave-lengths, modulation below 1 000 cycles may be rectified three times as strongly as the upper end of the scale, while with longer waves the defect is more serious still. It is also certain that audio-frequency harmonics will be set up; but these do not appear to be large so long as the percentage modulation of the transmitter is low.

Consideration of the effects obtained by variation of the resistance of the "leak" and the value of grid condenser leads the

[1] Colebrook: "The Rectifying Detector," E.W. & W.E., March, April and May, 1925.

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author to express the view that the present tendency is towards unnecessarily high leaks. His figure 21 shows that there is little gain by going above .5MO. But it seems advisable also to control the potential of the bottom end of the grid circuit—a point that we ourselves have found useful. In fact, he shows that for the best results, there should be variable grid-leak and condenser as well as a potentiometer! It would appear that accepted values of the condenser (.1 to .2$m\mu$F) are correct for broadcast wave-lengths.

After discussing anode rectification, the author finally draws up some general conclusions. Unfortunately, however, he finds it impossible to say definitely that one type or another is the best. For the efficiency of a given detector depends on the output load and the input circuit; on whether reaction is used, and on whether sensitivity or freedom from distortion is the prime object. He does point out, however, that anode rectification, while undoubtedly less sensitive than grid rectification for C.W., has particular advantages on telephony—especially on the longer wave-lengths or as second detector in supersonic work. He also draws attention to the advantages, for telephony, of a crystal coupled with a valve to provide regeneration. But it is impossible to abstract this section satisfactorily, and since it contains no mathematics, all readers are referred directly to it.

Marine Wireless. [R530·4

Inaugural Address by Major B. BINYON, O.B.E., M.A., Chairman of the Wireless Section, I.E.E.

THE opening meeting for the 1925-26 Session of the I.E.E. Wireless Section was held in the Institution Theatre, on Wednesday, 4th November, when Major B. Binyon (Managing Director of The Radio Communication Co., Ltd.) delivered his inaugural address as the new Chairman for the session.

The subject of the address was "Marine Wireless." This, said the Chairman, was a branch of wireless activity which—save perhaps for direction-finding—had received little attention at the Institution. He then gave a brief description of several different ship transmitters, illustrated by photographic slides. The sets shown were all of the "switchboard" self-contained and enclosed pattern, ranging from a ¼ to a 3½kW set suitable for either ship or shore station use. The lecturer commented on the advantage of this mode of assembly, as compared with the alternative plan of individual parts mounted in the cabin. The switchboard type was compact and convenient to handle, and was much superior in the ability which it gave to test both parts and the transmitter as a whole before installation.

A comparison was then given between the use of I.C.W. and spark transmission (both by quenched and synchronous gaps) for such transmission purposes. Whatever theoretical advantages either system might have, the ultimate test was necessarily one of audibility. An interesting table showing test results for the three different types of transmission was exhibited. The tests of transmission and reception fell into three classes, *i.e.*, (*a*) Equal Input Powers, (*b*) Equal Aerial Powers, (*c*) Equal Audibility Factors. The tests were all done under exactly similar conditions and received field strength and audibility of signals measured. Audibility was measured by the shunted telephone method, the shunt being reduced until signals were *just readable*, this method being found more uniform and reliable than the alternative of reduction to inaudibility. In the Equal Input Power Test, the I.C.W. system was distinctly superior both in audibility and field strength. For Equal Aerial Powers the I.C.W. gave the greater field strength measurement, but, curiously, the synchronous gap system gave superior audibility. The Equal Audibility Factors test show distinctly in favour of the I.C.W.

The lecturer next dealt with emergency apparatus in general, and more especially with this type of apparatus applied to the needs of lifeboat service. A complete transmitter and receiver set suitable for lifeboat

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installation was shown in the theatre, and further illustrated by slides, one of which showed the set suitably disposed in the lifeboat. This type had been thoroughly tested for weather-proofness, and contained the points of detail which these tests had shown necessary for the maintenance of the set. A waterproof sleeve permits the operator's arm to get weatherproof access for work, and one tuning control on the outside serves for both transmitting and receiving adjustment.

After briefly discussing ships' aerials and insulators, the Chairman then dealt with automatic call devices. In particular he described and illustrated an automatic call arrangement developed by his company, explaining the operation of the different relays and cams involved, by the aid of an extremely well-made diagram in which relay tongues could be closed, and he am contacts moved to assist the following of its operation. The apparatus was demonstrated in actual working, responding to a call of three dashes each of four seconds' duration and separated by one second spaces. This call was superimposed on two already interfering signals which failed to actuate the apparatus.

The final part of the lecture was devoted to direction finding. The well-known Robinson D.F. system was explained, with diagrams showing the combination of the E.M.F.s due to the main and the auxiliary coils which this system employs. The lecturer referred to the additional "90 degree ambiguity" which was possible, and demonstrated a neat model of "steering wheel" for frame control, incorporating the revers ng switch which is used to determine when the main coil is on the maximum line of the transmitter. A slight backlash is deliberately introduced into the motion of the wheel, and this backlash movement used to operate the reversing switch. A simple rule to "follow the weak direction" then enables the operator to obtain the final setting. The system was being made semi-automatic by the use of a galvanometer, giving zero deflection on either side of the reversing switch when the frame is correctly oriented. This was still in a "laboratory stage of development," as was also a further modification rendering the system completely automatic, *i.e.*, so that the main coil automatically set itself to lie in the plane of the transmitting station. This arrangement was briefly described, and very successfully demonstrated. A small loop at the back of the theatre served as transmitter and the frame as a receiver set itself parallel to the plane of the transmitter loop. Relays operated "Port and Starboard" lights on the frame, one or the other being lit so long as the frame was incorrectly oriented, flickering alternately and finally being extinguished as the frame assumed its final direction. "Quadrantal error" was well demonstrated by the holding of a large loop of metal more or less around the receiving frame. Finally the transmitter was slowly moved along the back of the theatre, its attendant receiving frame swinging with its transit.

A vote of thanks to the Chairman for his lecture was carried with acclamation, on the motion of Admiral of the Fleet, Sir Henry Jackson, and Mr. E. H. Shaughnessy, the retiring Chairman.

The Evershed Generator—A Further Note.

IN our report on the Evershed H.T. Generator (E.W. & W.E., November, p. 922), we qualified our otherwise entirely favourable report by a note that there was some difficulty in supplying by hand sufficient power to get full voltage when feeding an LS5 valve; and we suggested tentatively that since the modern tendency is towards the use of such valves (of fairly low impedance) it might be advantageous to wind the generator for slightly lower voltage and greater current.

The makers, Messrs. Evershed & Vignoles, Ltd., Acton Lane Works, Chiswick, point out that the type of generator tested by us is essentially designed for high impedance valves, and that another type is supplied for low impedance work with just the modification suggested.

It is probable therefore that we were rather overloading the one tested, and that with the other type we should have found the ripple even smaller than we did, for overloading usually increases this.

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The Rectification of Small Radio Frequency Potential Differences by means of Triode Valves.—Part II. [R134

By F. M. Colebrook, B.Sc., A.C.G.I., D.I.C.

12. *The transient condition.*

It is well known that a combination of a capacity and a resistance is unable to respond instantaneously to a change of potential distribution. In fact, the time required to pass from one equilibrium to another is theoretically infinite, but in practice the system will reach a condition indefinitely close to its real final equilibrium after a very short time. The circuits involved in grid rectification are of this character, and it will therefore be necessary to see what effect this will have on the rectification process.

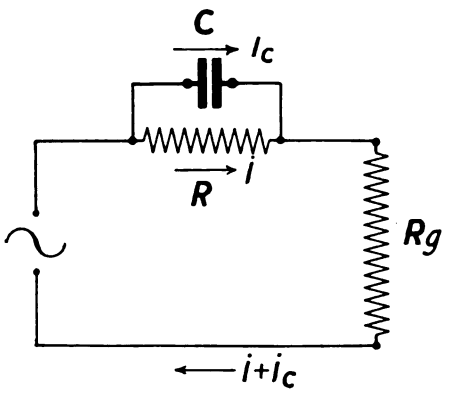

Fig. 17.

In order to simplify the problem the circuit will be considered in the form shown in Fig. 17, where the grid-filament path is represented as a constant resistance R. Actually it is, of course, a resistance which varies with the potential difference acting across it, this being the nature of its rectifying property. As far as the transient condition is concerned, however, it will be a sufficiently close approximation to consider it as constant at its mean value over the range of the changes involved.

If q be the charge on the condenser at any given instant the application of Kirchhoff's laws will give the equations

$$e = (i + i_c)R_g + iR \quad .. \quad (12.1)$$

$$= i(R + R_g) + i_cR_g \quad .. \quad (12.2)$$

$$\frac{q}{C} = iR \quad .. \quad .. \quad .. \quad (12.3)$$

$$i_c = \frac{dq}{dt} = CR\frac{di}{dt} \quad .. \quad .. \quad (12.4)$$

whence

$$\frac{de}{dt} = \frac{R + R_g}{CR}i_c + R_g\frac{di_c}{dt} \quad .. \quad (12.5)$$

There will be in general two parts to the solution of this equation. The first, known as the particular integral, is the solution of the equation as it stands, having regard to the nature of the time variation of the E.M.F. e.

The remaining part of the solution is known as the complementary function, and is derived from the equation

$$i_c\frac{(R + R_g)}{CR} + R_g\frac{di_c}{dt} = 0 \quad (12.6)$$

Dividing through by $\frac{R + R_g}{R}$ and putting

$$\frac{RR_g}{R + R_g} = R_0 \quad .. \quad (12.7)$$

(*i.e.*, R_0 is the resistance of R and R_g in parallel)

$$i_c + CR_0\frac{di_c}{dt} = 0 \quad .. \quad (12.8)$$

of which the solution is

$$i_c = k\varepsilon^{-\frac{t}{CR_0}} \quad .. \quad (12.9)$$

where k is a constant dependent on the initial conditions.

The time constant of the circuit is seen to be CR_0. It should be specially noted that the resistance involved in the time constant is not, as is sometimes stated, the

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grid-circuit resistance, but it is the latter in parallel with the (slope) resistance of the grid filament path.

As far as the reception of a continuous wave is concerned the modification of the foregoing analysis due to the existence of the time constant will be as follows: The change of mean grid potential will not take place instantaneously, the change of potential at any instant t being given by

$$v = v_c\,(1 - \varepsilon^{-t/CR_0}) \quad .. \quad (12.10)$$

This equation shows that the potential change will reach 99 per cent. of its final steady value in 4.606 CR_0 seconds. For an illustrative example we will take the following values :—

$$\begin{aligned} a &= 3 \times 10^{-6} \\ b &= 5 \\ R &= 2 \times 10^{6} \\ C &= .2 \times 10^{-9} \\ E &= .25 \\ v &= 0 \end{aligned}$$

The initial magnitude of R will be

$$\left(\frac{dv_g}{di_g}\right)_{-v_0} = \frac{1}{ab\varepsilon^{-bv_0}} \quad .. \quad (12.11)$$

and the final magnitude

$$\left(\frac{dv}{di}\right)_{-v_0-v_c} = \frac{1}{ab\varepsilon^{-b(v_0+v_c)}} \quad (12.12)$$

Both of these can be determined as already shown from the given data. The first is $.806 \times 10^6$ and the second 1.03×10^6, giving a mean value of $.918 \times 10^6$. This gives $.63 \times 10^6$ for R_0 and $.126 \times 10^{-3}$ for CR_0. Under these conditions the potential change will reach 99 per cent. of its final value in $.58 \times 10^{-3}$ seconds. A time constant of this magnitude will cause only a negligible loss of sensitivity even with high speed automatic transmission.

It is clear from the preceding section that the time constant could be still further reduced by the application of a small positive voltage to the grid, since this will very greatly reduce the slope resistance of the grid-filament circuit.

The exact analysis of the effect of the time constant in the reception of speech or music modulated waves is a very difficult matter. It would seem probable that where the modulation consists of a pure musical tone there will be no effect at all, and that even in the case of more or less "explosive" modulation such as might be associated with certain consonants in speech and with percussion in music the effect will be exceedingly small, especially as the time constant can be reduced to an exceedingly small value at the short wave-lengths used for broadcasting.

13. *The grid rectification of a modulated continuous wave.*

The preceding sections have all been devoted to the discussion of the rectification of a pure continuous wave. This is the fundamental case from a theoretical point of view, but one which in itself is of very little practical importance, since in the great majority of practical applications the E.M.F. to be rectified consists either of a modulated continuous wave or the sum of two high-frequency E.M.F.s of nearly equal frequency (*i.e.*, heterodyne reception). The first of these is of very general interest at the present time on account of its relation to broadcast reception. It must not be forgotten, however, that the term "modulated continuous wave" also includes those cases in which a single tone modulation is imposed on a carrier wave for the purposes of morse transmission.

The following discussion of the rectification of a modulated continuous wave seeks to answer the questions :—

(i.) What will be the nature and the magnitudes of the changes of grid potential given by the rectification of a modulated continuous wave ?

(ii.) What will be the nature and the magnitude of the output circuit currents given by these changes of grid potential ?

(iii.) To what extent will the changes of grid potential and the output circuit currents faithfully reproduce the modulation of the carrier wave ?

(iv.) What are the best conditions of operation ?

It will be shown that these questions can be answered more or less completely by a suitable extension of the analysis already given.

In view of the practical importance of the subject, it will be desirable to deduce as much as possible from the most general form of rectifying characteristic, considering separately the special applications of the analysis to the exponential form of characteristic.

It can be shown* that equation (5.6), which refers to the rectification of a con-

* See Appendix III.

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tinuous wave in the case of the general grid current characteristic, can be written in the form

$$i_0+i_c=F(E)+(v-v_0+v_c)F^1(E)+\frac{(v-v_0-v_c)^2}{2}F_2(E)+\frac{(v-v_0-v_c)}{3!}F_3(E)$$
$$\text{etc., } ad\ inf. \quad .. \quad (13.1)$$

where i_0 is the initial grid current and i_c is the continuous current produced by the rectification. Also

$$F(E)=\frac{1}{T}\int_0^T f(E\ sin\ \omega t)dt \quad .. \quad (13.2)$$

$$F_1(E)=\frac{1}{T}\int_0^T \frac{\delta f(E\ sin\ \omega t)}{\delta E\ sin\ \omega t}dt \quad .. \quad (13.3)$$

etc., etc.

A modulated continuous wave can be written in the form

$$e=(E+m)\ sin\ \omega t \quad .. \quad (13.4)$$

where E is the amplitude of the carrier wave and where m is the instantaneous value of some at present unspecified function of time constituting the modulation. It is shown in the appendix referred to above that for an E.M.F. of this character equation (13.1) becomes :—

$$i_0+i_c+i_m=F(E)+mF'(E)+\frac{m^2}{2}F''(E)$$
$$\text{etc., } ad\ inf.$$
$$+(v-v_0-v_c-v_m)\left\{F_1(E)+mF_1'(E)+\frac{m^2}{2}F_1''(E)\ ..\ \text{etc., } ad\ inf.\right\}$$
$$+\frac{(v-v_0-v_c-v_m)^2}{2!}\left\{F_2(E)+mF_2'(E)+\frac{m^2}{2}F_2''(E)\ ..\ \text{etc., } ad\ inf.\right\}$$
$$+\frac{(v-v_0-v_c-v_m)^3}{3!}\left\{F_3(E)+mF_3'(E)+\frac{m^2}{2}F_3''(E)\ ..\ \text{etc., } ad\ inf.\right\}$$
$$\text{etc., etc., etc., } ad\ inf. \quad (13.5)$$

where

$$F'(E)=\frac{dF(E)}{d(E)}\ ...\ \text{etc., etc.} \quad (13.6)$$

In the above i_m is written for the whole group of currents due to the modulation, and v_m for the back E.M.F. due to the passage of these currents through the grid circuit impedance, *i.e.*, the grid-circuit resistance in parallel with the grid condenser.

The rather formidable collection of equations (13.5) can be analysed by the well-known principle of equating separately the components of equal frequency. Thus, the continuous component is given by

$$i_0+i_c=F(E)+(v-v_0-v_c)F_1(E)+\frac{(v-v_0-v_c)^2}{2}F_2(E)\ ...\ \text{etc.,}$$
$$+(\qquad\qquad) \quad (13.7)$$

where the last brackets contain a number of terms derived from the square and higher powers of m multiplied by the higher derivatives of $F(E)$, and terms containing products of m and v_m and powers of v_m. The detailed examination of any practical case will show that these terms are very small compared with the remainder. If they are omitted equation (13.7) becomes the same as equation (13.1), indicating that the continuous component is not appreciably affected by the modulation. This is a fact which can be confirmed experimentally, at least for transmissions such as broadcast telephony where the modulation percentage is kept low.

For the determination of the modulation frequency terms, it will be necessary to specify the nature of the time variation of m. In general this will be a periodic function of irregular and changing wave shape. The analysis of such a case would be so complex as to obscure the important features of the solution. It will be preferable, therefore, to consider the simplest possible case, that of a single sine wave modulation

$$m=M\ sin\ nt \quad .. \quad .. \quad (13.8)$$

This will make it possible to form some idea of what will happen in the general case.

In the first place, it will be seen that equation (13.5) contains terms in m^2 and higher powers of m, and also product terms containing m and v_m and higher powers of v_m. It is clear therefore that the modulation frequency currents will comprise a whole Fourier series. Since the modulation contains one frequency only all the other frequencies are extraneous and are introduced by the rectification process. The latter therefore involves some degree of frequency distortion, since, with a modulation of irregular wave form it will alter the relative intensities of the harmonics, each harmonic giving rise to a complete Fourier series of its own. In practice, however, these extraneous frequencies will be of very

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small amplitude compared with the fundamental, since the higher derivatives of the rectification characteristic $F(E)$ will be relatively small, and since terms containing powers of v_m will be very small indeed. This is particularly true for carrier wave amplitudes greater than about .4 volt associated with modulation percentages not exceeding 15 per cent. or so.

The fundamental frequency equation derived from (13.5) is comparatively simple in form. Putting i_n and v_n for the fundamental frequency components,

$$i_n = m\left\{ F'(E) + (v - v_0 - v_c)F_1'(E) + \frac{(v-v_0-v_c)^2}{2} F'_2(E) \ldots \text{etc. } ad\ inf. \right\} - v_n/R_c \qquad (13.9)$$

where

$$\frac{1}{R_c} = F_1(E) + (v - v_0 - v_c)F_2(E) + (v - v_0 - v_c)F_3(E) \ldots \text{etc. } ad\ inf. \quad .. \quad (13.10)$$

It should be noted that the expression multiplying m and the expression for $1/R_c$ depend only on the circuit and on the carrier wave amplitude. They are constants with respect to the modulation.

The physical significance of the above equation can be made more clear by expressing it in terms of $\frac{\delta v_c}{\delta E}$, *i.e.*, the slope of the rectification characteristic for the given carrier wave amplitude. It then becomes*

$$i_n = \left(\frac{1}{R} + \frac{1}{R_c}\right)\frac{\delta v_c}{\delta E} m - \frac{v_n}{R_c} \quad .. \quad (13.11)$$

Since i_n and v_n are simple harmonic functions, they can conveniently be expressed in vector form as the vectors $\mathbf{V}_n$ and $\mathbf{I}_n$. The modulation can be similarly represented by the vector $\mathbf{M}$. Then, since

$$\mathbf{V}_n = \dot{Z}_n \mathbf{I}_n \quad .. \quad (13.12)$$

where $\dot{Z}_n$ is written for the grid circuit impedance operator at the frequency $n/2\pi$, equation (13.11) becomes

$$\mathbf{I}_n = \left(\frac{1}{R} + \frac{1}{R_c}\right)\frac{\delta v_c}{\delta E}\mathbf{M} - \frac{\dot{Z}_n \mathbf{I}_n}{R_c} \quad .. \quad (13.13)$$

i.e.,

$$\mathbf{I}_n = \frac{\left(1 + \frac{R}{R_c}\right)\frac{\delta v_c}{\delta E}\mathbf{M}}{R_c + \dot{Z}_n} \quad .. \quad (13.14)$$

*See Appendix III.

The current is therefore that which would be produced by an alternating E.M.F. represented by a vector $\mathbf{E}_n$, associated with an internal resistance R_c, acting in a circuit of external impedance $\dot{Z}_n$, where

$$\mathbf{E}_n = \left(1 + \frac{R}{R_c}\right)\frac{\delta v_c}{\delta E}\mathbf{M} \quad .. \quad (13.15)$$

i.e.,

$$\mathbf{I}_n = \frac{\mathbf{E}_n}{R_c + \dot{Z}_n} \quad .. \quad (13.16)$$

In grid rectification, however, the important quantity is not $\mathbf{I}_n$ but $\mathbf{V}_n$, the change of grid potential. This is obviously given by

$$\mathbf{V}_n = \frac{\dot{Z}_n}{R_c + \dot{Z}_n}\mathbf{E}_n \quad .. \quad (13.17)$$

It should be noted that the limiting value for $\mathbf{V}_n$, which occurs when $\dot{Z}_n = R$, *i.e.*, at low frequencies, is

$$\mathbf{V}_n = (\delta v_c/\delta E)\mathbf{M} \quad .. \quad 13.18$$

which is otherwise obvious. At any frequency for which $\dot{Z}_n$ differs appreciably from R (being always less than R) the magnitude of $\mathbf{V}_n$ will be correspondingly reduced. This is an exceedingly important point, for it shows that the rectification efficiency depends on audio-frequency. The effect of this in producing amplitude distortion will be considered later.

To determine the magnitude of the frequency effect it will be necessary to express $\dot{Z}_n$ in terms of C and R. Since $\dot{Z}_n$ is the impedance of these two in parallel,

$$\frac{1}{\dot{Z}_n} = \frac{1}{R} + jpC, \text{ where } p = 2\pi \times \text{frequency}. \qquad (13.19)$$

Substituting this value for $\dot{Z}_n$, the frequency factor can be expressed in the form

$$\frac{\dot{Z}_n}{R_c + \dot{Z}_n} = \frac{-j\dfrac{\frac{1}{R} + \frac{1}{R_c}}{pC}}{-j\dfrac{\frac{1}{R} + \frac{1}{R_c}}{pC} + 1} \cdot \frac{R}{R + R_c} \qquad (13.20)$$

$$= \frac{-jx}{1 - jx} \cdot \frac{R}{R + R_c} \qquad (13.21)$$

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where

$$x = \frac{1}{pC}\left(\frac{1}{R} + \frac{1}{R_c}\right) \quad .. \quad (13.22)$$

Therefore

$$\mathbf{V}_n = \frac{-jx}{1-jx}\,\frac{R_c}{R_c+R}\cdot\frac{R_c+R}{R_c}\,\frac{\delta v_c}{\delta E}\,\mathbf{M} \quad (13.23)$$

This gives as the amplitude equation

$$\mathbf{V}_n = k_n \frac{\delta v_c}{\delta E}\,\mathbf{M} \quad .. \quad (13.24)$$

k_n being the frequency factor, of magnitude

$$k_n = \frac{x}{\sqrt{1+x^2}} \quad .. \quad (13.25)$$

The curve of the function k is shown in Fig. 18. By means of this curve the variation with frequency can be determined for any given values of R, C, and R_c.

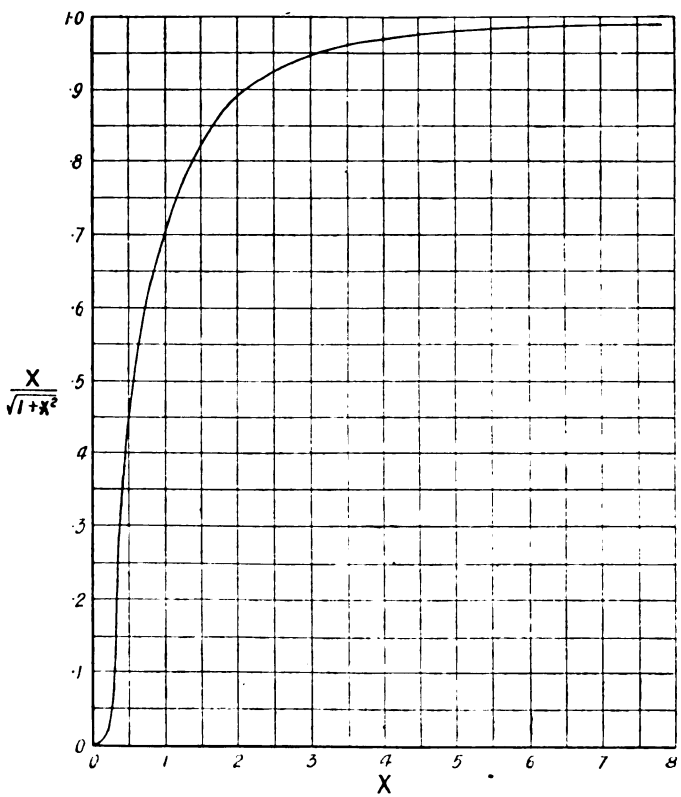

Fig. 18.

Application to the Exponential Characteristic, and Numerical Example.

The above analysis refers to any grid-current characteristic. To relate it to the exponential characteristic given by small receiving valves it is only necessary to put

$$f(e) = ae^{be} \quad .. \quad (13.26)$$

The substitution presents no difficulty and is given in outline in Appendix IV. It will be found that, using symbols already defined,

$$\frac{1}{R_c} = \frac{b(v_0+v_c)}{R} \quad .. \quad (13.27)$$

For this type of characteristic, therefore,

$$x = \frac{1+b(v_0+v_c)}{pCR} \quad .. \quad (13.28)$$

The variation with frequency can thus be calculated for any given values of a, b, C, R, v, and E. As a typical example, consider the valve used for the experimental confirmation described in Section 8, assuming a value of two megohms for R, $v = 0$, and $E = .5$ volt. The corresponding value of $b(v_0 + v_c)$ is 3.75. It will be shown later that C cannot be reduced below a certain value at any given radio-frequency without a loss of sensitivity due to a fall of high-frequency voltage. Suppose that this value is about .000 2 microfarads at a wavelength of 365 metres. The variation of the frequency factor over an audible frequency range of 250 to 6 000 p.p.s. for this value of C is shown in the upper curve of Fig. 18*a*. It will be seen that there is a variation of nearly 300 per cent. with frequency. Now suppose that the above signals are superheterodyned to about 3 500 metres, requiring a grid

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condenser of about .002 microfarads if a drop of high-frequency voltage is to be avoided. The lower curve of Fig. 18*a* shows the variation of the frequency factor in this case, *i.e.*, from about .7 to about .035, amounting to 2 000 per cent. The greater part of this variation occurs at the lower frequencies, so that the distortion effect will not be as pronounced as the analysis would suggest. It is obvious, however, that there is a very material loss of sensitivity.

The above example shows that the grid rectification of modulated continuous waves has certain inherent defects which increase in importance as the wave-length of the carrier wave increases. Even at a wave-length of 365 metres the frequency variation, associated also with a loss of sensitivity at high audible frequencies, is very pronounced. As the wave-length increases there is clearly a compromise to be made between a loss of sensitivity due to a fall of high-frequency voltage in the grid condenser, about which more will be said later, and a loss of sensitivity associated with frequency distortion on account of the audible frequency effect described above. The physical interpretation of the effect is that the grid condenser is required to fulfil two conditions :—

(*a*) Its radio-frequency impedance must be low compared with R_1, the radio-frequency input resistance.

(*b*) Its audio-frequency impedance must be high compared with the resistance of R in parallel with R_t, the effective internal modulation frequency resistance of the rectifying circuit.

Only at very short wave-lengths can these conditions be even approximately fulfilled simultaneously. Also, an applied positive grid voltage is not likely to improve matters very much, since this will decrease R_1 and consequently call for a larger value of C to fulfil condition (*a*).

In considering the effect of this frequency factor on the purity of reproduction question (ii) above must be answered. The analysis need not be given in full, since it is well known that the anode circuit can be thought of as very approximately a simple series circuit in which a certain multiple of the grid voltage acts in series with a certain internal resistance and the load impedance. (Equation (4.3).) The mutual efficiency of the load-impedance—internal resistance combination is necessarily one which varies with frequency in an easily calculable manner, increasing or decreasing with frequency according as the load impedance is less than

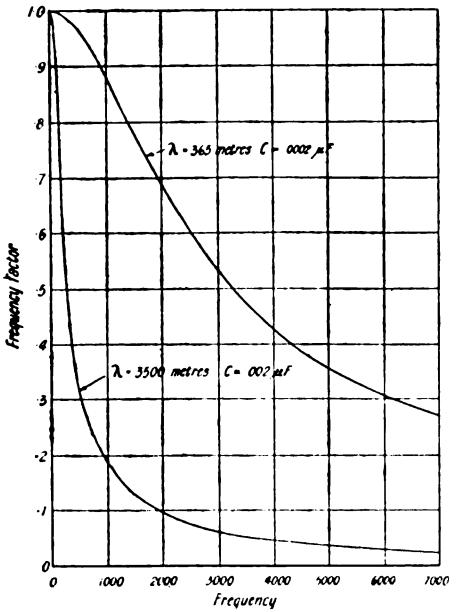

Fig. 18*a*.

or greater than the internal resistance. In general, unless the load impedance is very high, even at low frequencies, the anode circuit will tend to a higher efficiency at the higher audible frequencies. This is likely to be the case when the load is a pair of ordinary telephones. The two distortions are in such a case opposite in character, and may partially neutralise one another. The matter is further complicated by the response characteristic of the telephones themselves, a matter on which information is lacking. It is therefore impossible at this stage to make any general pronouncement as to the seriousness of the frequency distortion effect described above. It is desirable, however, that its existence should be known, and in no case can the associated loss of sensitivity be advantageous.

In conclusion, it would admittedly be much more satisfactory to have direct experimental confirmation of this frequency effect. Such measurements, however, would present formidable practical difficulties. A certain degree of practical conformation

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can be obtained by substituting a variable condenser up to, say, .002 or .003 microfarads for the usual small fixed condenser in a grid rectifying circuit, and then listening to any convenient broadcast transmission. It will be found that there is a very pronounced loss of apparent sensitivity as the grid condenser is increased. The effect on quality is not so easy to judge owing to the great variation in intensity of the signals.

It will be shown later that the frequency factor plays an equally important part in heterodyne reception.

14. *Heterodyne reception with grid rectification.*

It was shown in the paper on the general theory of rectification referred to above* that given a continuous wave signal

$$e_1 = E_1 \sin(\omega_1 t + \theta_1) \quad .. \quad (14.1)$$

and a locally induced E.M.F.

$$e_2 = E_2 \sin(\omega_2 t + \theta_2) \quad .. \quad (14.2)$$

acting together on the terminals of a rectifying circuit, then the sum of the two could be represented by

$$e = e_1 + e_2 = E \sin(\omega t + \alpha) \quad .. \quad (14.3)$$

where

$$E^2 = E_1^2 + E_2^2 + 2\, E_1 E_2 \cos(nt + \beta) \quad (14.4)$$

$$n = (\omega_1 - \omega_2) \quad .. \quad .. \quad .. \quad (14.5)$$

$$\omega = \frac{(\omega_1 + \omega_2)}{2} \quad .. \quad .. \quad .. \quad (14.6)$$

$$\beta = \theta_1 \sim \theta_2 \quad .. \quad .. \quad .. \quad (14.7)$$

and

$$\tan \alpha = \frac{E_1 \sin\left(\frac{nt}{2} + \theta_1\right) - E_2 \sin\left(\frac{nt}{2} + \theta_2\right)}{E_1 \cos\left(\frac{nt}{2} + \theta_1\right) - E_2 \cos\left(\frac{nt}{2} + \theta_2\right)}. \quad (14.8)$$

For convenient abbreviation the resultant amplitude can be expressed in the form

$$E^2 = E_r^2 + e_n \quad .. \quad .. \quad (14.9)$$

where

$$E_r^2 = E_1^2 + E_2^2 \quad .. \quad .. \quad (14.10)$$

and

$$e_n = 2\, E_1 E_2 \cos(nt + \beta) \quad .. \quad (14.11)$$

i.e., e_n is an E.M.F. the amplitude of which is twice the product of the signal and local E.M.F. amplitudes, and whose frequency is the difference between the signal and the local oscillation frequencies.

*"The Rectifying Detector." E.W. & W.E., March, April, May, 1925.

The discussion of the effect of an E.M.F. such as e on a grid rectifying circuit will clearly be very similar to that already given for the case of a modulated continuous wave. To save space and avoid repetition the analysis will not be given in full, as it will be sufficient to indicate the necessary modifications of the expressions involved.

In equation (13.2) the mean value of the characteristic function is expressed as a function of the amplitude of the high-frequency E.M.F. It could, of course, be equally well expressed as a function of the square of the amplitude, *i.e.*,

$$\frac{1}{T}\int_0^T f(e)\, dt = S(E^2) \quad .. \quad (14.12)$$

and similarly for the related functions $S_1(E^2)$, $S_1'(E^2)$, etc.

The Taylor Theorem expansion will then take the form

$$S(E^2) = S(E_r^2 + e_n) \quad .. \quad .. \quad (14.13)$$

$$= S(E_r^2) + e_n S'(E_r^2) + \frac{e_n^2}{2!} S''(E_r^2) + \frac{e_n^3}{3!} S'''(E_r^2)$$

etc., etc., *ad inf.* .. (14.14)

The development of the analysis will then follow exactly the same lines as in Section 13, but the result will be expressed in terms of $\delta v_c / \delta E_r^2$, *i.e.*,

$$i_n = \left(\frac{1}{R} + \frac{1}{R_c}\right) \frac{\delta v_c}{\delta E_r^2}\, e_n - \frac{v_n}{R_c} \quad (14.15)$$

where R is now expressed in terms of the S functions, but has exactly the same value as before.

In the above, i_n and v_n are respectively the current and back E.M.F. of fundamental beat frequency $n/2\pi$. As explained in Section 13, double and higher multiple frequencies will also be produced, derived from the second and higher derivatives of $S(E_r^2)$, but these will be of relatively small amplitude.

The final amplitude equation will be similar to (13.24), *i.e.*,

$$V_n = \frac{x}{\sqrt{1 + x^2}} \cdot \frac{\delta v_c}{\delta E_r^2} E_n \quad .. \quad (14.16)$$

where x has the values already given in Section 13.

Expressed in terms of $\delta v_c / \delta E_r$ this becomes

$$V_n = \frac{x}{\sqrt{1 + x^2}} \frac{\delta v_c}{\delta E_r} \frac{E_1 E_2}{E_r} \quad (14.17)$$

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In practice E_2 will be large compared with E_1, so that very approximately

$$E_r = E_2 \quad .. \quad .. \quad .. \quad (14.18)$$

therefore

$$V_n = \frac{x}{\sqrt{1+x^2}} \frac{\delta v_c}{\delta E_2} E_1 \quad .. \quad (14.19)$$

The variation of the frequency factor has already been discussed. It will in all cases be less than one and, under certain conditions, particularly at long wave-lengths, it may be as low as .01. It will therefore profoundly modify the effective sensitivity of this method of reception.

Apart from this beat frequency effect, the change of grid potential is proportional to $E_1 \frac{\delta v_c}{\delta E_2}$. In Fig. 19 is shown as a typical example the variation of the slope of the rectification characteristic with amplitude for the valve and circuit conditions described in Section 8. The slope is obviously not proportional to E, so that with grid rectification V_n is not proportional to the product of the two E.M.F.s, as is usually stated. In fact, for large values of E, beyond the limit of the exponential range, the rectification characteristic becomes very nearly a straight line, *i.e.*, $\delta v_c/\delta E$ becomes constant. Beyond this point no further increase of signal strength will be obtained by increasing E_2.

It must be clearly understood that the above discussion applies only to heterodyne reception with a separate oscillator. Reception of the same type in which the receiving valve is also the source of the local oscillation is generally known as autodyne, and will be considered later.

15. *Suitable magnitudes for the grid condenser and the grid-circuit resistance.*

So many factors enter into the determination of the most suitable magnitudes for C and R that, in spite of the comparatively simple analysis of the rectification process which has been given in the preceding sections, no comprehensive statement can be made as to the best values for these quantities in terms of the grid constants a and b, and the frequency of operation. All that will be attempted in this section will be a brief discussion of the dependence of the rectification process on the magnitudes of C and R.

It has already been shown that the product CR should be kept as small as is consistent with efficiency in order that the time constant of the rectifying circuit shall be small, and in order that the frequency factor in the rectification of modulated continuous waves shall vary as little as possible. Both C and R must therefore be kept as small as possible. These two factors will be considered separately.

(*a*) *The grid-circuit resistance.*

In the general case, the change of mean grid potential v cannot be expressed explicitly in terms of R. By taking a numerical example it was found that the nature of the dependence of v on R did not vary greatly with the signal amplitude. This indicates that conclusions obtained from the simpler case of small signal amplitudes will not be misleading in the general case. As shown in Section 9, for small signal amplitudes

$$v_c = \frac{bv_0}{1+bv_0} \frac{G(bE^2)-1}{b} \quad .. \quad (15.1)$$

also

$$bv_0\epsilon^{bv_0} = abR\epsilon^{bv} \quad .. \quad (15.2)$$

Now the right hand side of equation (15.1) contains a factor of the form $x/(1+x)$ where $x\epsilon^x = abR\epsilon^{bv}$. A curve showing the variation of $x/(1+x)$ with $x\epsilon^x$ will therefore indicate the nature of the variation of v_c with $abR\epsilon^{bv}$, *i.e.*, with R for given values of the other constants. The curve is illustrated in Fig. 20 (overleaf). Its chief characteristic is its extreme flatness for values of $x\epsilon^x$ greater than about 10. As a general

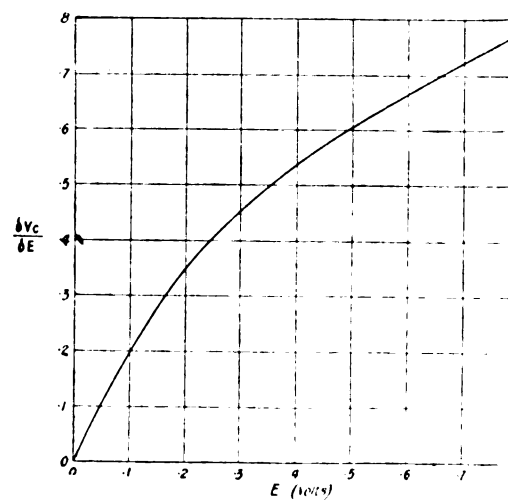

Fig. 19.

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efficiency condition it can therefore be stated that $abR\varepsilon^{bv}$ shall not be less than about 10. It is true that v_c will continue to increase with R beyond this point, but the increase will be relatively small. The right value for R will obviously depend very greatly on v. By way of illustration the curves of Fig. 21 show the calculated variation of v_c with R for $v = 0$ and $v = .5$, for a valve having the grid constants

$$a = 3 \times 10^{-6}$$
$$b = 5$$

and for a signal amplitude of .1 volt. It will be seen that they are of the same general shape as the curve of Fig. 20, being in point of fact, simple multiples of this curve. Since the theory on which these curves are based has been verified as described by experiment, they are probably very accurately representative of the variation concerned.

It seems likely from these results that the general tendency is to use grid-resistances of much higher value than is really necessary, especially if a positive continuous potential is applied to the grid. Further, it would appear that the most reliable way to ensure the best conditions in any given case will be to use both a variable grid resistance or "grid-leak" as it is usually called, and a grid potentiometer.

(*b*) *The grid condenser.*

The function of the grid condenser is to provide, for the high-frequency components of the current in the grid circuit, a path of which the impedance is low compared with that of the grid-filament path. As already stated, its magnitude should be no larger than is necessary to fulfil this condition.

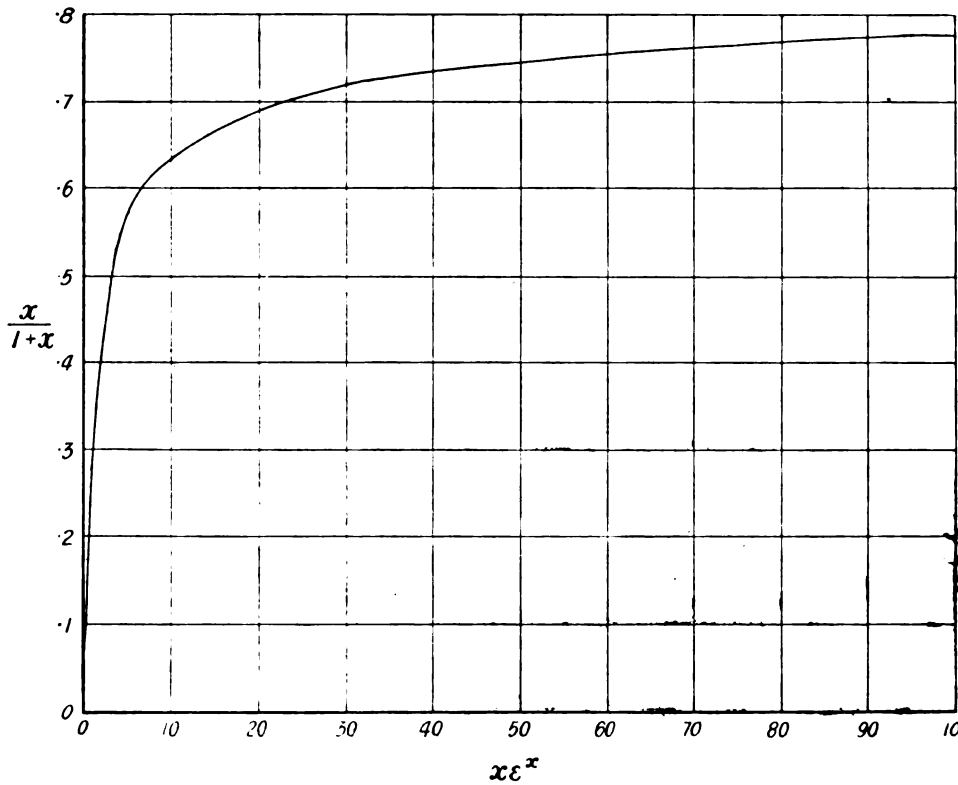

Fig. 20.

The actual effect of the magnitude of C on v_c is not easy to calculate in the general case. Some idea of the nature of the variation can, however, be obtained from the following approximate analysis, which will be nearly correct for small signal amplitudes and provided C is not far removed from a value which fulfils the above condition.

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For a small signal amplitude the high-frequency resistance of the grid-filament path approaches $1/bi_0$, i_0 being the initial value of the continuous grid current. For

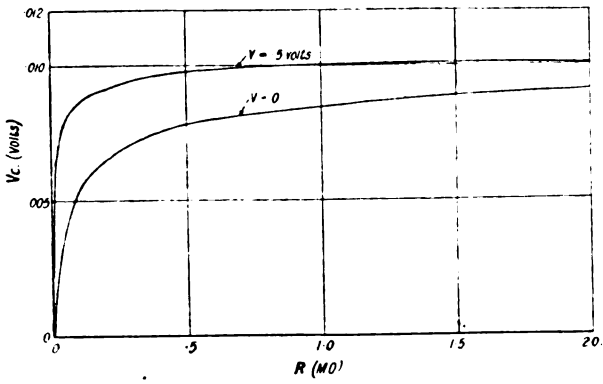

Fig. 21.

a signal frequency $\omega/2\pi$ the impedance of the grid condenser will be $1/j\omega C$. Assuming that the condenser impedance is small compared with the grid-filament resistance, it will be even smaller compared with the grid-circuit resistance or "grid-leak" and the shunt effect of the latter on the condenser impedance can be neglected. If **E** and **E′** represent respectively the vector signal E.M.F. and the vector E.M.F. which operates on the grid of the valve, then,

$$\mathbf{E}' = \frac{1/bi_0}{1/bi_0 + 1/j\omega C}\,\mathbf{E} \qquad (15.3)$$

$$= \frac{j\omega C/bi_0}{1 + j\omega C/bi_0}\,\mathbf{E} \qquad (15.4)$$

Thus the variation of **E′** with **E** is represented by an operator fraction of which the magnitude is of the form $x/\sqrt{1+x^2}$, where $x = \omega C/bi_0$. For small signal amplitudes the change of mean grid potential will be proportional to E_s^2, E_s being the root mean square value of the signal E.M.F., so that the variation of v_c with C will be of the form $x^2/(1+x^2)$. The curve of this function is shown in Fig. 22. Its most important characteristic from the present point of view is its extreme flatness for values of x greater than about 4.

This therefore specifies approximately the minimum value for C, *i.e.*,

$$\omega C/bi_0 < 4 \text{ or } C < 4bi_0/\omega \qquad (15.5)$$

The best value for C thus depends not only on the signal frequency but also on the grid-filament resistance for the point of operation. No general figure can therefore be given, and all that can be said is that the admittance of the condenser at the given frequency should be at least four times the grid-filament slope conductivity. Very little is to be gained by increasing C beyond this point as far as continuous wave rectification is concerned, and, as already shown, the rectification efficiency for modulated continuous waves or for heterodyne may be considerably reduced by doing so.

It should be clear that the minimum value of the grid condenser will increase very rapidly with the initial grid potential, owing to the increase of bi_0. Thus in

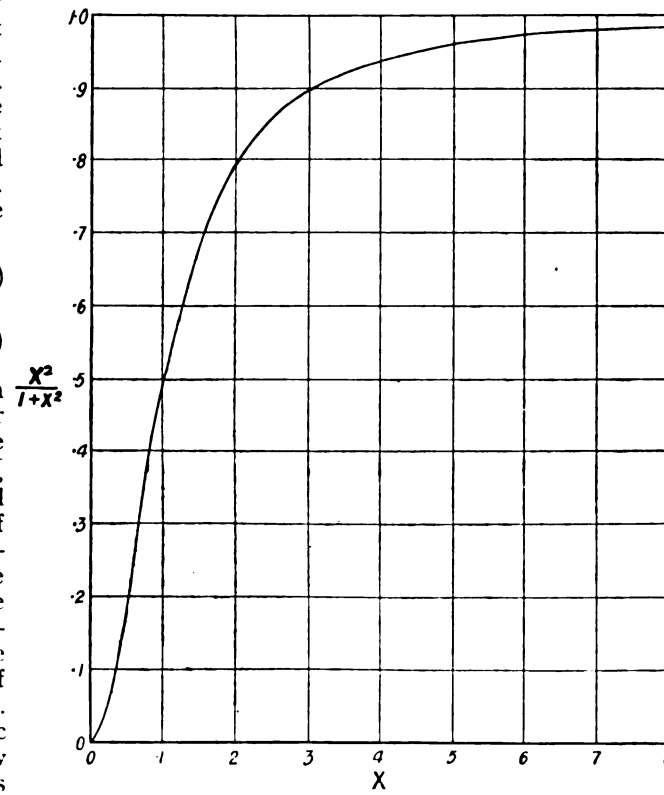

Fig. 22.

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practice the increase of sensitivity which should result from an increase in bi_0 may

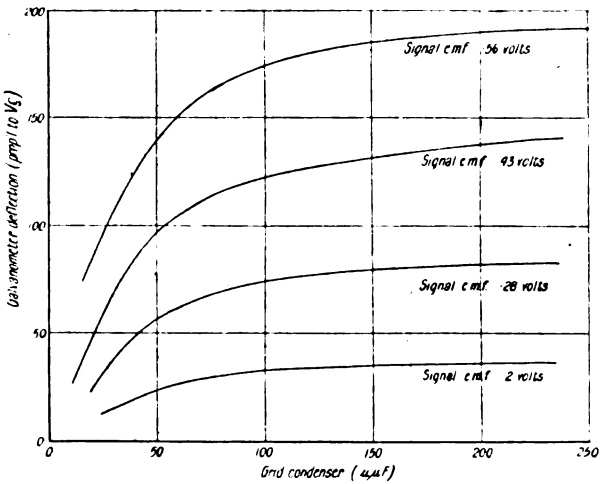

Fig. 23.

sometimes be cancelled by the opposite variation of the ratio of ωC to bi_0. It appears that the most efficient conditions in any given case can only be ensured by means of independent variation of R, of C, and of the initial grid potential.

As an illustration of the above analysis, we have for the valve considered in Section 8,

$$a = 3.16 \times 10^{-6}$$
$$b = 5.55$$
$$R = 1.89 \times 10^{6}$$
$$v = 0$$

$\lambda = 400$ metres, *i.e.*, $\omega = 4.72 \times 10^{6}$ For this case the calculated value of bi_0 is 1.35×10^{-6}. It will be found that $\omega C/bi_0 = 4$ corresponds to about $114\mu\mu$F for C. Thus, for small amplitudes at least, the curve showing the variation of v_c with C should flatten out in the neighbourhood of this value for C. The curves of Fig. 23, which were obtained by actual measurement, give a very satisfactory confirmation of this simple analysis.

APPENDIX III.

The initial equation is

$$i_0+i_c = \frac{1}{T}\int_0^T f(v-v_0-v_c+e)\,dt$$

where

$$e = E \sin \omega t.$$

By Taylor's Theorem, the integrand can be expanded into

$$f(v-v_0-v_c+e) = f(e)+(v-v_0-v_c)\,f'(e)+\frac{(v-v_0-v_c)}{2!}f''(e)+\frac{(v-v_0-v_c)}{3!}f'''(e)\ldots\text{etc.}$$

where

$$f'(e) = \frac{\delta f(e)}{\delta e}\ldots\text{etc., etc.}$$

The integration therefore gives

$$i_0+i_c = F(E)+(v-v_0-v_c)\,F_1(E)+\frac{(v-v_0-v_c)}{2!}F_2(E)+\frac{(v-v_0-v_c)}{3!}F_3(E)\ldots\text{etc., } ad\ inf.$$

where

$$F(E) = \frac{1}{T}\int_0^T f(E \sin \omega t)\,dt$$

$$F_1(E) = \frac{1}{T}\int_0^T f'(E \sin \omega t)\,dt\ldots\text{etc., etc.}$$

For the solution of the case in which the E.M.F. is modulated it will be necessary to consider certain integrals of the form

$$\frac{1}{T}\int_0^T f\{(E+m)\sin \omega t\}dt.$$

For these integrations it will be necessary to assume that m does not change appreciably during one high-frequency cycle. Under ordinary conditions of practical wireless telephony this assumption will not introduce any appreciable error. We shall then have

$$\frac{1}{T}\int_0^T f\{(E+m)\sin \omega t\}dt = F(E+m).$$

The above equation will now take the form

$$i_0+i_c+i_m = F(E+m)+(v-v_0-v_c-v_m)\,F_1(E+m)+\frac{(v-v_0-v_c-v_m)}{2!}F_2(E+m)\ldots\text{etc., } ad\ inf.$$

Also, by Taylor's Theorem,

$$F_n(E+m) = F_n(E)+mF_n'(E)+\frac{m^2}{2!}F_n''(E)+\frac{m^3}{3!}F_n'''(E)\ldots\text{etc., } ad.\ inf.$$

where

$$F_n'(E) = \frac{\delta F_n(E)}{\delta E}\ldots\text{etc., etc.}$$

Equation (13.5) can now be obtained by the expansion of the $F_n(E+m)$ functions above. In these equations i_m is written for the whole group of modulation frequency currents, and v_m for the back E.M.F. due to these currents.

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For expression in terms of $\delta i_c/\delta E$,

$$\frac{\delta(i_0+i_c)}{\delta E} = F'(E)+(v-v_0-v_c)F_1'(E)+ (v-v_0-v_c)^2 \frac{}{2} F_2'(E) \ldots \text{etc.}$$

$$-\frac{\delta(v_0-v_c)}{\delta E}\left\{ F_1(E)+(v-v_0-v_c)\ F_2(E) + \frac{(v-v_0-v_c)^2}{2} F_3(E) \ \ldots \text{ etc., } ad\ inf. \right\}$$

i.e.,

$$\frac{1}{R}\frac{\delta v_c}{\delta E} = F'(E)+(v-v_0-v_c)F_1'(E)+ (v-v_0-v_c)F_2'(E) \ldots\ldots - \frac{\delta v_c}{\delta E}\ \frac{1}{R_c}$$

Therefore

$$F'(E) + (v-v_0-v_c)F_1'(E) + \frac{(v-v_0-v_c)^2}{2} F_2'(E) \ \ldots\text{etc., } ad\ inf.$$

(To be continued.)

Two New "Silvertown" Products.

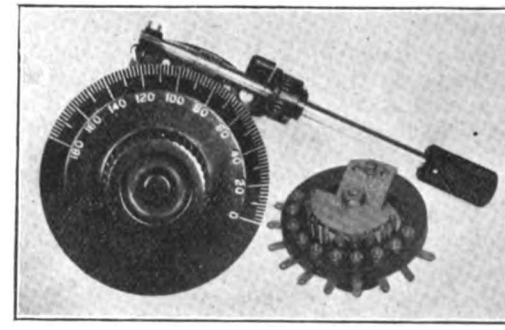
FROM the Silvertown Company, Silvertown, E1,6, we have received two components for test—their "Verniometer" and a 10-way switch.

The verniometer is a slow-motion device for use with condensers, variometers, and so on. It consists essentially of an ebonite knob and dial of the ordinary type, screwed rigidly to a brass plate of the same diameter as the dial and toothed at its periphery.

A worm drive is mounted separately on the panel, so that the worm gearing engages with the toothed plate on the dial. The worm spindle also carries a vernier indicator and a pointer for the main dial reading is provided on the worm bracket. The gearing, which can be thrown out of action at will for the main adjustment, provides a reduction of 240 to 1, is very smooth in action, and there is a noticeable absence of backlash. The device is very well made, and reasonably priced at 6s.

The 10-way switch is designed for mounting under the panel, and requires only two screws for fixing. The switch consists of a circular ebonite former, with the spindle mounted in the centre, and 10 contact points mounted radially around half its circumference.

A semi-circular contact segment, notched at each end, moves round the contact points, and it will be appreciated that as the contact segment is moved, connection is made to each contact point successively.



The two "Silvertown" accessories.

The switch is equally useful for connecting inductances or condensers. It is priced at 5s. 6d., complete with white ivorine scale and drilling template.

Proposed Institute of Radio Engineers.

At a meeting held on Saturday, 31st October, at the Hotel Russell, London, it was decided that the registration of the Institute should be proceeded with. In the absence of Mr. Nelson, who was indisposed, Mr. C. E. Baldwin occupied the Chair.

The following officers and members of the Council were elected :—

Chairman, Mr. Nelson ; Vice-Chairman, Mr. E. H. Turle ; Hon. Sec. and Treasurer, Mr. Y. W. P. Evans ; Assistant Hon. Sec., Mr. H. King.

Council : Mr. A. F. H. Baldry, Mr. H. W. Gambrell, Mr. C. E. Baldwin, Mr. J. H. Tanton, Mr. W. E. Cooper, Mr. A. Woodmansey.

The following were appointed district representatives : Mr. J. H. Tanton, London Area ; Mr. C. E. Baldwin, S.E. Counties ; Mr. Lowe, S.W. Counties ; Mr. Gambrell, Midlands ; Mr. Woodmansey, N.E. Counties ; Mr. Bradshaw and Mr. Simpson, N.W. Counties. Others will be appointed as necessary. The Headquarters of the Institute will be situated in London.

The next General Meeting will be held at the International Correspondence School, Kingsway, where a room has been placed at the disposal of the Institute, through the kind offices of Mr. R. P. Baker, the managing director.

Official Recognition of Esperanto.

In accordance with the recommendation of the Fifth General Assembly of the League of Nations, the International Conference of the Member States of the Universal Telegraphic Union has just accorded official recognition to Esperanto.

Article 7 of the International Telegraphic Regulations, dealing with the use of international languages has been completed as follows :—

"The use of Latin and Esperanto is allowed in the same way."

Esperanto is therefore officially recognised as a "clear language" for international telegraphy.

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Notes on the Conditions Governing Transatlantic Reception.

By S. K. Lewer (6LJ). [R113

SINCE the work of Cash and Burne, carried out during the latter end of 1923,* all interest in the reception of transatlantic signals seems to have disappeared. In all probability this was because it became a simple matter to log dozens of American amateurs on even a single-valve receiver. Most of the tests were in connection with the phenomenon of fading, but as this practically disappeared when shorter waves (80-100 metres) were used, there was apparently no need for further tests in that direction. At my own station throughout the whole of last year I listened to the American amateurs regularly, and a study of the log of reception has yielded a very interesting graph. This will be discussed in detail later in this article.

The first attempt at reception was made on the morning of 2nd December, 1923, and resulted in a log of 23 Americans. The next two mornings on which I listened, 9th and 16th December, the totals were 37 and 46 respectively. This increase was thought to be due to the gain in experience and the increase in the efficiency of the receiver, and consequently the results of these nights were neglected for the purposes of the graph. It was found that the best time for listening was from 03.30 G.M.T. onwards on Sundays, which is from 22.30 onwards on Saturdays on the East Coast of the United States. This, of course, was before the days of no "quiet hours." Consequently, a regular watch was kept at this time, and the total number of different Americans heard went up in leaps and bounds. The totals for the separate nights varied enormously and did not appear to be connected in any way with other observations.

During February several improvements were made in the receiver, but after that I decided to listen right through the summer and to study the conditions of reception without varying anything at the receiving end. The receiver was therefore maintained at constant efficiency.

A detailed log of reception was kept, including time, station called, station calling, audibility, tone, wave-length, and if necessary, notes on fading. All these details were recorded in the interest of checking the reports with the transmitters' logs. Much valuable time was lost by doing this, but in view of the fact that, in all, about 800 Americans have asked for detailed reports, I feel that my time has not been spent in vain.

Nothing really remarkable happened until 13th April, when 73 Americans were logged. This beat the previous record of 46 on 16th December. On 13th April conditions were exceptionally good, and signals from about 60 of the stations logged were read on a loud-speaker of the home-made variety and which was somewhat inefficient. It may be mentioned at this point that the receiver consisted of L.F. with the usual low-loss tuner. The aerial was a single wire, 50 ft. long and 25 ft. high, and was 10 to 20 ft. below the tops of the neighbouring houses. I was rather surprised at being able to log so many stations "on one hook," and decided to try the next night. I succeeded in logging 48, and being still more enthusiastic, I sacrificed several hours of sleep during the next night, and was rewarded with a total of 4. At this stage conditions were rather erratic. On 27th April static was terrific and very few Americans were logged. The totals, however, rose to 16 on 4th May, and to 21 on 18th May, after which the figures never reached higher than 9 until 3rd August with a total of 27.

The chief trouble that I experienced during the summer months was the very short time in which signals could reasonably be expected to be audible in England. The Atlantic Coast stations did not begin their "brass-pounding" until 22.30 E.S.T., which is 03.30 G.M.T. The sun rises in

* E.W. & W.E., Vol. III, p. 132.

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London at about 03.45 G.M.T. in the middle of June, leaving a period of approximately 15 minutes during which the Atlantic is in darkness. Consequently, it was useless to listen before 03.30 G.M.T. and the Americans faded out completely shortly after 04.00 G.M.T. Static was generally very bad and blotted out all weak signals. Another reason for the smallness of the figures is that a large number of the best stations suspended their activities during the summer on account of static and external attractions.

After the year's work a graph was drawn showing the totals per night against the time measured in Sundays, but it was apparently of no interest, except for several erratic changes which could not be explained.

The wave-lengths used throughout these tests varied from time to time. During the first few months the reception was carried out on the 150-200 metre band only. Following this, however, the region of 100 metres proved very fruitful, and since the autumn hundreds of Americans tried the new wave-band of 75-80 metres. The strength of their signals at this end increased enormously, and they pounded into Europe in such numbers that they became almost beyond control. A comparison of the logs of several English receiving stations showed that very few Americans were received at more than one station during a period of several hours. In other words, many more American stations are being heard in this country than can be logged with one receiver. As an example of the increased efficiency of the 75-80 metre band over the old 150-200 metre band, I may say that the total number of different Americans logged at my station increased from 200 to 300 during February, when the 150-200 metre band was used. This was with a 2-valve receiver. The total increased from 800 to 1 000 during November, while using the 75-80 metre band and only a single-valve receiver. The increase of 200 in November is remarkable, because the total was already very high, and one would naturally expect new stations to be scarce, especially on a single-valve receiver. The change of wave-length did not alter the shape of the graph, which seems to hold even for the 40-metre and 20-metre bands.

Another factor which found its way into transatlantic reception with the coming of short waves was the change of the operating hours. The American amateurs were prohibited, during the 150-200 metre days, from beginning the night's work until 22.30 local time, on account of the possibility of interfering with the transmissions from broadcasting stations. With the advent of the use of short waves (below 80 metres) the interference caused to broadcast listeners by transmitters working on the short waves was considered to be negligible, and transmission at any time of the day or night was permitted. This is now proving very useful in obtaining more accurate figures.

Since the graph showing the variations in the periodic totals was useless, it seemed that the periodic watch had been useless apart from bringing joy into the hearts of scores of American amateurs at having "got over on a fiver." A graph showing the variations in the strength of one particular station from week to week, or better, the variations in the average strength of several stations, would have yielded much useful information. The measurement of signal strength is, however, a difficult operation, and is rarely accurate. If measurements were taken on one transmitting station, the results would hold only for that particular location; and to measure the strength of the signals received from dozens of American stations in a few hours would indeed be very tedious, if not impracticable. On looking through the logs, however, it was found that on some nights many stations were logged in a short time, but on other nights very few were logged in a comparatively long time.

Now, fortunately, every transmission intercepted had been logged, which means that some stations were logged several times in one night. The idea of this was to give the transmitting operator as much information concerning his signals as possible. The number of log entries in a given time could therefore be taken as a measure of the conditions. This method was perfectly satisfactory while the 150-200 metre band was in use, but when the 75-80 metre band was introduced the number of stations logged was simply a measure of the operator's efficiency, since there were always crowds of stations that could be heard at the same time. For this reason only a single-valve receiver was used for the 75-80 metre band, so as to bring the number of stations logged within controllable limits. Changing the

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receiver was quite permissible, since, for the purpose of plotting a graph, only the variations in the number of stations logged from week to week were required.

A graph was then plotted showing the number of log entries per night divided by the number of successful listening hours per night against the time measured in Sundays, and is reproduced in Fig. 1. The dotted portions will be referred to later. This was certainly not so erratic as the graph showing the totals per night. The year was divided into the four seasons, the dates of the divisions being 23rd March, 22nd June, 21st September and 21st December. At this stage the graph assumed a very interesting aspect. By comparing the shape of the section of the graph for the winter season with that for the summer we observe a definite similarity. In fact, the variations coincide from week to week. There is also a similarity between the spring and autumn sections, but in these the graph has a different shape. Of course, the rates at which stations were logged on the various nights are not the same in these sections, but this is immaterial, since we are concerned for the moment with the variations in conditions and not with the number of Americans we may hope to receive in a given time.

The portion of the graph covered by the dates 31st August to 21st September marks a much needed rest. The shape during this interval is based upon observations made at two or three other receiving stations. It will be observed that this section conforms to one's expectations on comparing with the winter section. At the four divisions the conditions are temporarily bad. It is interesting to note that at the winter and summer solstices, that is to say, when the sun is "standing still," the graph slowly comes down to a minimum and then rises yet more slowly as if tending to remain thus; and at the vernal and autumnal equinoxes, when the sun is in the middle of its swing "crossing the equator," the graph makes a very sharp dip.

Again, at the end of every two months beginning with February, April, the conditions are exceptionally unfavourable. These bi-monthly periods, however, do not seem to fit in with the seasonal variations and solar influence. Notwithstanding this, it was found that, on comparing these dates, there was a new moon in the vicinity of the bi-monthly minimum. The mention of the

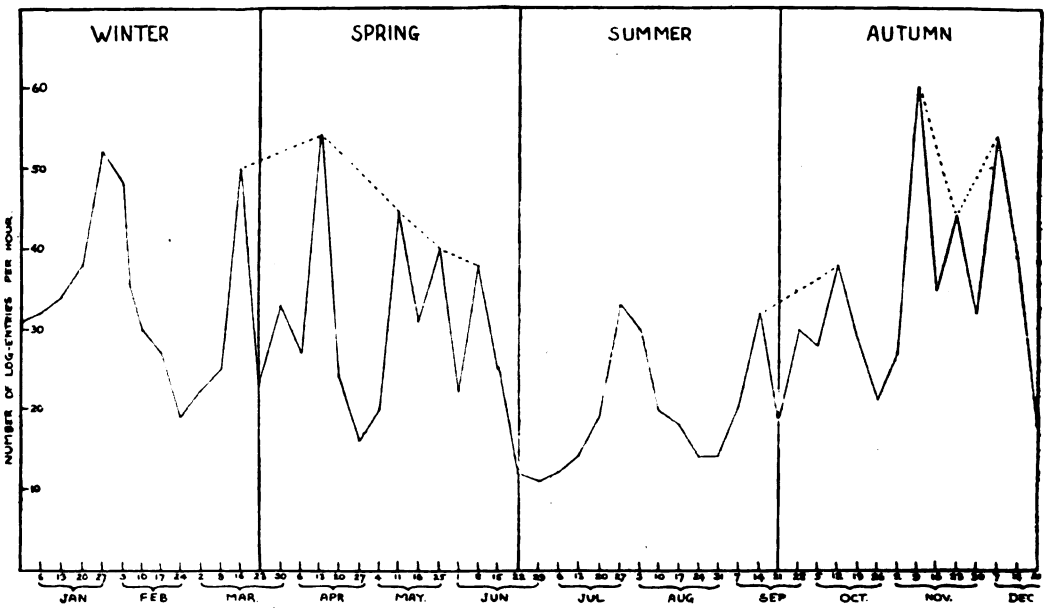

Fig. 1.

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moon may come as a surprise to many, and in fact, no explanation concerning its influence is forthcoming. Some recent experiments made in America have indicated the doubtful presence of a connection between the phases of the moon and atmospheric interference. Referring again to the graph, the conditions during the winter seem to be favourable whenever there is a full moon. When all facts are taken into consideration, however, it is very doubtful whether long distance communication is affected by the moon in any way.

One interesting point in the graph is the height of the summer section. Contrary to one's expectations, the conditions were quite favourable during this period. Accurate measurements could not be taken because of the very small numbers of log entries, which were accounted for by the fact that the listening period was so very short, as previously explained.

Another method of measuring the variations in conditions would be to determine the length of time after sunrise in England during which the Americans could be heard. This method would certainly be much less tedious than the one that I employed but, unfortunately, there are three objections to this. Firstly, in winter, when sunrise is very late, the American stations may close down before daylight would decrease their range. Secondly, in mid-winter and mid-summer, daybreak occurs very slowly, indirectly making accurate determination of the time of complete fading next to impossible. Thirdly, complications may be introduced by having a mixed medium of darkness and daylight. It would be a difficult task to investigate the conditions covering the intervening space if a portion of it were in darkness and the remainder in sunlight, since, as is now well-known, the sun has a very marked effect upon the refracting and reflecting properties of the ionised layers in the upper atmosphere. A fourth objection may be raised. The range of a transmitter working on waves of the order of 200 metres is increased to a very large extent during the night. The same thing occurs on waves in the vicinity of 100 metres; in this case both day and night ranges were increased. When the wave is reduced to about 40 metres, the day range becomes quite considerable and the night range is increased still more. On further reduction of the wave to the neighbourhood of 20 metres, the day range becomes greater than the night range, and the range of this wave during the day is greater in a direction away from the sun, due to the change in the slope of the reflecting layer with respect to the earth's surface.* Now we can see where the fourth objection comes in.

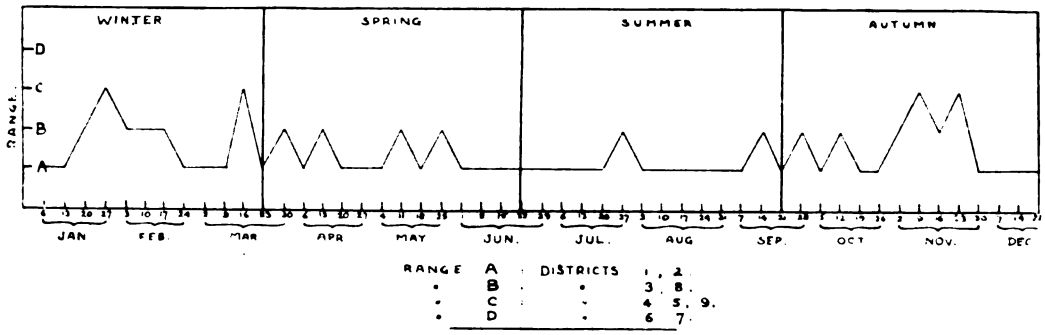

Fig. 2.

The range and the length of time after sunrise during which signals may be audible would depend to a large extent upon the wave-length of the transmitter and the direction of the received wave.

Perhaps a more fruitful but tedious method of determining the changes in the conditions would be to compare the maximum ranges obtained. I used this method in the modified form as a check for the graph in Fig. 1. The graph obtained is shown in Fig. 2. On comparing it with Fig. 1, we can see at once a marked similarity

* *Q.S.T.*, April, 1925.

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in the shape. The procedure was as described below.

The numbers of the stations that I had heard in each of the nine districts of the United States were counted and expressed as percentages of the "total percentages." The numbers of the stations in the nine districts heard on each night were counted and expressed as percentages of the total for the night. These were the "nightly percentages." There was found to be, almost invariably, one district having an exceptionally large "nightly percentage" when compared with the "total percentage" for that particular district. If there were two or three districts with an extra large "nightly percentage," they were at approximately the same distance. Thus, if more than the average number of stations in the distant districts are logged on a particular night, the maximum range covered was exceptionally great and conditions were better. The nine districts were divided into four groups or ranges with approximately 1 000 miles between them. The groups were :—

A : 1st and 2nd. 3 000 miles.
B : 3rd and 8th. 4 000 miles.
C : 4th, 5th and 9th. 5 000 miles.
D : 6th and 7th. 6 000 miles.

The graph was then drawn showing the range, *i.e.*, the district or districts in which the extra number of stations was heard. against the time measured in Sundays as before. Although this method of finding the maximum range has not, to the best of my knowledge, been used before, it appears to be very effective. It is interesting to note that the apparent range obtained on 13th April was not exceptional, yet, from the graph in Fig. 1, conditions were undoubtedly very favourable on that date. This discrepancy may be explained either by the fact that so many strong East Coast stations could be heard that the more distant, and therefore weaker, stations were jammed out, or by the fact that the conditions for the reflection of waves from the more distant stations may have been poor. The former explanation seems to be more feasible.

We may therefore assume that the graph in Fig. 1, corroborated by the graph in Fig. 2, is a fair representation of the conditions during 1924 of the reception of American signals in England. It may also represent the conditions of the reception of English signals in America. Mr. A. G. Wood, of G5RZ, has plotted a graph of the conditions of reception during the months of October and November by simple estimation. This coincides approximately with my own graph. He also plotted a graph showing the conditions of the reception of his signals in America by the comparison of reports. This was coincident with the reception graph.

There is another point bearing on this subject. On looking at the graph in Fig. 1, we see that the conditions at the end of the year were very unfavourable. American signals were undoubtedly weaker at that time. One night early in the New Year, while in communication with several American stations, I asked for a report of the strength of European signals during the previous few nights. Some reported that they had heard very few Europeans, and others had not even heard anything of us. This, together with the other evidence, seems to indicate that the conditions are identical for the passage of signals in either direction.

It is doubtful whether this graph would hold for the reception of signals from New Zealand or Australia, since those stations are in the other hemisphere, and also darkness would never, or perhaps only for a few minutes, cover the entire distance between the stations. Yet, considering that our summer season is coincident with the winter season in the Antipodes and that the shape of the graph for the pairs of seasons is the same, we could probably forecast the dates on which signals from the Antipodes would be exceptionally strong. However, it is easier to transmit signals in a direction north-south than in a direction east-west, due probably to the influence of the earth's field, and results would be entirely different.

Now let us consider the possible causes of these variations in the conditions as represented by the graph. Since the earth's surface is curved, and signals are presumed to travel above the earth's surface, then there must be a reflecting surface, so that the waves are returned to the earth. There is ample evidence to show the existence of such a surface. The phenomenon of fading cannot be explained without a variable reflecting surface. The presence of a reflecting

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surface in the form of a layer of ionised atmosphere is confirmed by the variations in the magnetic field of the earth. This layer is world-wide and more or less permanently ionised. The ionisation is caused by ultra-violet radiation from the sun, and is at a maximum during the day, and diminishes gradually during the night. The conductivity of this layer is greatest when the sun's zenith distance is least, and varies with sunspot minimum to sunspot maximum. Its height has been estimated at 50 kilometres, but this may vary with the time of the day or night.

At first sight this does not seem to be the layer which we use in covering great distances at night. If the intensity of ionisation decreases during the night, it seems that the extent of reflection of the waves must also decrease. But this is not what we find in practice. The ionisation of this layer is at a minimum just before dawn, and we can all agree that conditions are no less favourable at dawn than at any other time of the night (for waves of 40 metres and above, at any rate).

Some experiments were recently carried out in order to plot a graph showing the variations in the strength of signals across the Atlantic over a period of 24 hours. This graph is shown in Fig. 3, together with the intensity of ionisation. From this it appears that (*a*) no use is made of the world-wide ionised layer, and (*b*) the sun's rays reduce the range and the signal strength of a station at a given point. It has been suggested that night-distortion and errors in direction finding work at night prove the existence of an ionised layer during the night.

We may therefore assume that the intensity of ionisation does not fall off to zero during the night. But it seems that, if the intensity is weaker at night, then the signal strength should be less. This, however, does not fit in with practice (for waves above 40 metres). It is commonly thought that the day range of short-wave transmissions is small because the wave energy is absorbed in the ill-defined lower surface of the ionised layer. During the night it is supposed that the lower surface becomes sharper, thus forming a more efficient reflector for the waves. If this layer is the one which is directly ionised during the day and the intensity falls off during the night, we should expect a decrease in the range of a station on the fall of night. But this does not occur (except for ultra-short waves), and we are led to imagine an ionised layer which comes into action after sunset. However, on considering the fact that Fessenden in 1900 found that the world-wide ionised layer is at a height

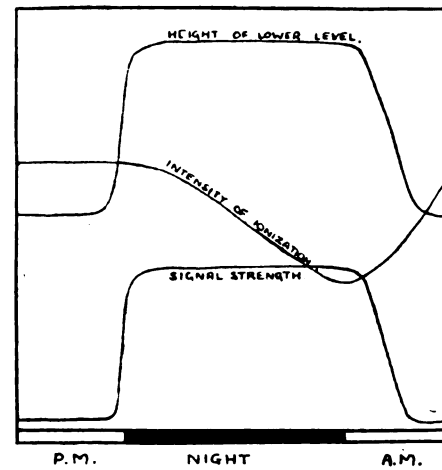

Fig. 3

of about 150 kilometres (*i.e.*, the lower surface) in the daytime, and rises to about 500 kilometres at night, we see the possibility of the varying height being responsible for the varying reflecting properties.

As a matter of fact, the lower figure of 150 kilometres is much higher than the figure generally agreed upon. Auroras have often been observed at a height of several hundred kilometres from the earth's surface, which indicates that the layer is very thick. The reason for the rising of the lower surface at nightfall is, of course, that on the removal of the source of ionisation, the sun, the layer settles out at a higher level.

Before we proceed, however, let us consider the known facts about short-wave long-distance communication. The most important fact is that the shorter the wave-length, the greater the range, either during the day or the night, for waves above 40 metres.

On waves of the order of 10 000 metres, the day and night ranges are the same. The range of 20-metre signals seems to be greater during the day than during the

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night. As has been explained in an earlier part of this article, the wave-lengths used throughout the year were not the same, but the changes had apparently no effect on the shape of the graph.

Now, it can be proved that shorter waves penetrate into the ionised layer to a greater extent than the longer waves. If the wave-length has no effect on the shape of the graph (for waves below 200 metres, at any rate), it seems that the height to which the waves penetrate in the layer does not affect the shape of the graph. Therefore it is highly probable that the graph does not represent the changes in the height. It is interesting to note that the variations in the signal strength of 20-metre signals from week to week conform remarkably well to the shape of this graph.

Waves in the neighbourhood of 200 metres are particularly suspectible to fading. Around 100 metres little or no fading is noticed, but in the region of 40 to 20 metres, fading is often very bad. It has been found that fading for waves of about 200 metres is regular and proceeds in cycles, the frequency being inversely proportional to the distance covered. Moreover, the fading cycles often occur superimposed on much slower cycles, but this is not often very noticeable. No tests have yet been carried out on the band around 20 metres.

Another peculiarity is that fading, even on one wave-length, does not always occur. According to the theory of the late Dr. Heaviside, the wave, in the process of being reflected from the ionised layer, remains in it for a short space of time, and on arrival at the receiving station meets the direct or earth wave with which it sets up very slow beats, and fading of the signal is the result. This assumes that the waves travel through the earth, or, at any rate, along the surface of the earth, with reasonable efficiency.

There is, however, a belief that short waves are very readily absorbed by solid bodies, and, in fact, it has often been shown that a hill or a building acts very effectively as a screen for short waves. Yet fading occurs even in signals from the Antipodes, in which case the path of the earth wave is at least 8 000 miles long. At this distance the earth wave would probably be inaudible, and no fading would result ; and again, fading is often noticed on waves of 20 metres at great ranges, where the chances of the earth wave getting through are very small. In view of what has been said on the phenomenon of fading, it is hardly possible that the graph in Fig. 1 is a curve of very slow fading throughout the year.

It is interesting to note that magnetic storms occurred on 23rd January, 30th March and 21st May, which are near three maxima on the graph, and also on October 25th, a minimum. When any magnetic changes occur there are always parallel changes in the sunspot frequency or area. A sunspot may exist for any length of time from a few minutes to several weeks, and its area is of the order of 6 by 10^7 square miles; but, unfortunately, no information on the activities of sun spots on these dates is available. Beyond this, there is apparently no connection between the graph and terrestrial magnetism with its attendant phenomena. Magnetic storms are generally accompanied by auroras, but there has been found to be no connection between auroras and wireless waves.* It has been said by some investigators that wireless waves do not penetrate intc the auroral layer, but this is to be doubted if the auroral layer indicates the height of the ionised layer.

It has been suggested by Fleming† that the variation of the inductivity of the air with height might be an aid or an alternative to ionic refraction, *i.e.*, the bending of the space wave. It therefore seems probable that the graph in Fig. 1 may be a representation of the variation of the inductivity of the air.

There is a very interesting connection between this graph and the graph showing the variations in the air-earth current in Fig. 4. This is the curve which is most similar to Fig. 1, and is the graph taken at Potsdam during some experiments made eleven years ago. This air-earth current is dependant on the intensity of ionisation at a given height, and is carried almost entirely by the heavy ions of low mobility. The light ions are much less numerous and have about 3 000 times the mobility of the heavy ions.

If the graph in Fig. 1 does represent the changes in the ionisation of the upper atmos-

* *British Assoc. Comm.*, 1914.
† *Proc. Phys. Soc.*, Aug., 1914.

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phere, it is not necessarily a representation of the variations in solar ionisation, since, besides ultra-violet radiation from the sun, the other possible sources of ionisation include radioactive emanation in the air, photo-electric effects at the ground, and gamma rays from radium and thorium in the ground. The breaking of waves has been suggested as a source of ionisation over oceans.* Consequently, the graph in Fig. 1 may represent the variations in any of these sources. This is hardly possible, however, in view of the connection with solar influences in the seasonal variations, and the only source of ionisation we may suspect is ultra-violet radiation.

Interest also centres around tropical storms which, according to one report, cause variations in signal strength, generally an increase.

There is an ionised region in the polar caps caused by collision of corpuscles emitted from sun spots, and brought to rest at a distance of about 80 kilometres from the earth's surface by the viscosity of the atmosphere. The effect of these ionised zones would probably be felt only in communication with the Antipodes, in which case the path of the wave would pass through the auroral zone and the polar caps. It is therefore unlikely that the graph represents the changes in the ionisation of the atmosphere in these regions.

It is probable that the graph represents the variations in the atmospheric ionisation caused by the sun and other sources, and if the effects of these supplementary sources could be removed, the graph due to solar variations would, in all probability, be a simple curve.

In conclusion, it may be said that the shape of the graph for this year and also on waves around 20 metres is coinciding with the shape of the graph for last year. A most important point is that if the graph is repeated every year—twice yearly in fact—we shall know exactly when conditions will be favourable and when to arrange our long distance tests. At present we are at the end of a sunspot cycle which lasts 11.1 years, and this may have an effect upon the shape of the graph.

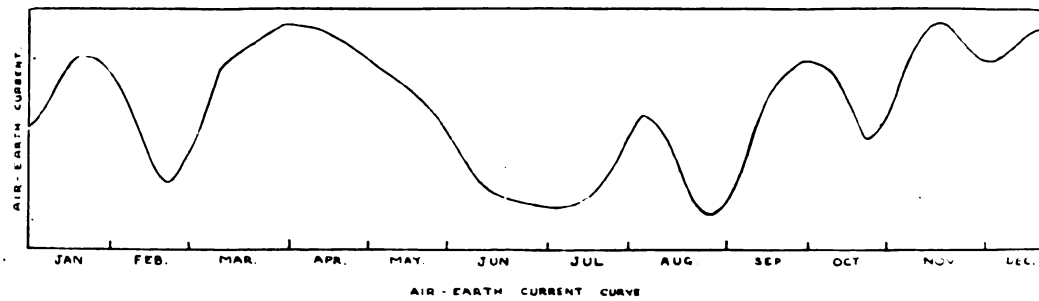

Fig. 4.

Unfortunately, in practically all experiments of this nature, there is an enormous amount of what we may call "spade work" to be done, and all the tests are necessarily spread over a long period of time. The writer hopes, however, that his investigations will be one step further in the explanation of the facts concerned with atmospheric ionisation on which so much depends at the present time. The work that has been done recently on 20 metres is not yet thoroughly understood, and doubt still hangs over our ideas of wave propagation, reflection and refraction. At any rate, the entire subject depends upon atmospheric ionisation, and it appears that this will have to be thoroughly understood before we can succeed in interplanetary communication.

* *Proc. Phys. Soc.*, Feb., 1925.

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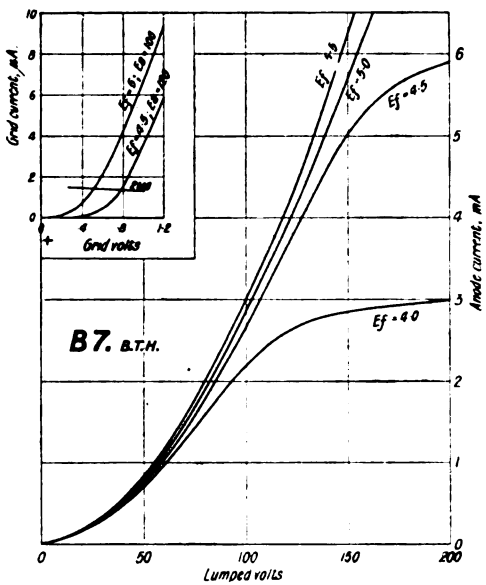
Some Valves Tested. [R333·009

We have now tested a fairly large batch of new valves in our laboratory, eight of which are described below. A further selection will be given in a later issue.

The B.T.-H. B7.

THIS is a dull emitter power valve, similar in construction to the B4 and B6, and designed for a 6-volt filament battery, but taking much less current than the B4. It is, in fact, a member



of our "606" class, and since the makers put the voltage amplification factor at 8.0, it just comes within the HL 606 class. It may, if desired, be used with dry batteries.

The sample submitted, we found, could be run successfully at less than 6.0 volts on the filament, though since the filament currents were somewhat

Fil. Volts. Ef	Fil. Cur. If	Sat. Plate Cur. Is	Anode Impedance. Ra	Voltage Ampli. μ	Power Ampli. P. $\left(=\frac{1\,000\mu}{Ra}\right)$	Filament Efficiency. F $\left(=\frac{Is}{Watts}\right)$
4.0	.066	3.2	31 000	11.5	4.2	12
4.5	.072	6.5	21 000	9.4	4.2	20
5.0	.078	11	17 000	9.3	5.1	29
5.5	.083	21	12 500	8.0	5.1	46

greater than those given in the makers' rating, the actual filament wattage was about normal.

We tested the valve at 4.0, 4.5, 5.0 and 5.5 volts on the filament, the corresponding currents being .066, .072, .078 and .083 amp.

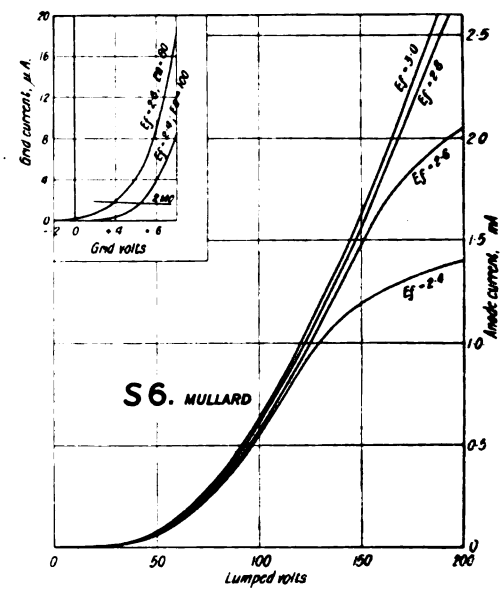
The saturation current, 21mA at 5.5 volts on the filament, is rather low, but should reach the normal value at 6.0 filament volts. The amplification factor was found to be in the neighbourhood of 8, as will be seen from the table of results. The impedance, 12 500 ohms at 5.5 filament volts, is rather higher than usual, although not seriously so.

The curves show that for distortionless L.F. work a fairly high anode voltage will be required (with suitable grid-bias), with at least 5.0 volts on the filament. The valve will probably work best as a first stage L.F. amplifier.

For use as a detector, a valve with a sharp bend in the grid current curve is essential. If this valve is used for this purpose, a fairly high value for the grid-leak is advisable.

Mullard S6.

This is made by the Mullard Radio Valve Co., Ltd., and is a dull emitter valve of the "test-tube" type, made with a special helmet shaped cap, and designed to fit into standard anti-capacity clips.



It is intended, so the makers state, for rectification, though it may be used satisfactorily as an H.F. amplifier or a resistance-coupled L.F. amplifier.

Being rated at 3 volts, 0.2 amp, and having a very high amplification factor, it comes in our HH. 320 class.

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We tested it at filament voltages of 2.4, 2.6, 2.8 and 3.0. As will be seen from the table, the filament currents ranged from 0.19 to 0.22 amp. The maximum saturation current obtained (at 3.0 volts) was 7.75mA, which is sufficient for the purpose for which the valve is designed. The anode impedance dropped to 36 000 ohms at 3.0 volts, though the makers rate it as high as

Fil. Volts. Ef	Fil. Cur. If	Sat. Plate Cur. Is	Anode Imped-ance. Ra	Voltage Ampli. μ	Power Ampli. P $\left(=\frac{1\,000\,\mu^2}{Ra}\right)$	Filament Efficiency. F $\left(=\frac{Is}{\text{Watts.}}\right)$
2.4	.19	1.5	70 000	16.6	3.8	3.3
2.6	.20	2.5	60 000	22	8	4.8
2.8	.21	4.75	40 000	18	8	8.2
3.0	.22	7.75	36 000	20	11	11.9

100 000 ohms. Since the amplification factor proved to be 20 at this voltage (rated at 22), the valve is better than would be expected from the makers' rating.

As a detector it should perform quite well. A 2 MO leak is about right.

As an amplifier, nothing much is gained by exceeding 2.8 volts on the filament. The curve, at high lumped voltages, straightens out nicely, and since the amplification factor is high, the valve should perform well as an H.F. amplifier. It is doubtful whether it could handle enough power for resistance coupled L.F. work, at least in stages other than the first. Nevertheless it is a good valve and the anti-capacity mounting should be useful in short-wave work. Price, 27s. 6d.

Mullard PM4.

This is a power valve, rated at 3.8 volts, 0.1 amp. In construction it is novel. The electrodes are

Fil. Volts. Ef	Fil. Cur. If	Sat. Plate Cur. Is	Anode Imped-ance. Ra	Voltage Ampli. μ	Power Ampli. P $\left(=\frac{1\,000\,\mu^2}{Ra}\right)$	Filament Efficiency. F $\left(=\frac{Is}{\text{Watts.}}\right)$
2.8	.110	4.5	17 000	4.8	1.35	14.6
3.2	.116	11.0	15 000	6.9	3.2	30
3.6	.123	18.0	11 500	6.9	4.1	41
4.0	.130	25.0	9 000	6.3	4.4	47

arranged horizontally, and are of a flattened box shape. The filament is in the shape of an "N." The bulb is pipless and slightly tapered.

The makers state that the valve can be run from dry cells, but a 4-volt accumulator is preferable, particularly as the filament current was found to exceed the rated value somewhat.

The results we obtained for the other constants of the valve agree very well with those of the makers.

At 4.0 volts on the filament, as will be seen from the table, the saturation current was 25mA, the anode impedance 9 000 ohms and μ was 6.3.

For first stage L.F. work, where the grid swing is fairly small, the valve could be worked at 4.0 volts on the filament and 120 lumped volts. With a grid-bias of —3 volts, this would involve an anode voltage of $120+(3\times6.3)$, say, 140 volts. For second stage work, the lumped voltage would probably need to be higher for distortionless results.

From the grid current curves, it can be seen that the valve should be a good detector at 4.0 filament volts and 60 anode volts, with a 2 MO leak. Price, 22s. 6d.

Ediswan PV6. D.E.

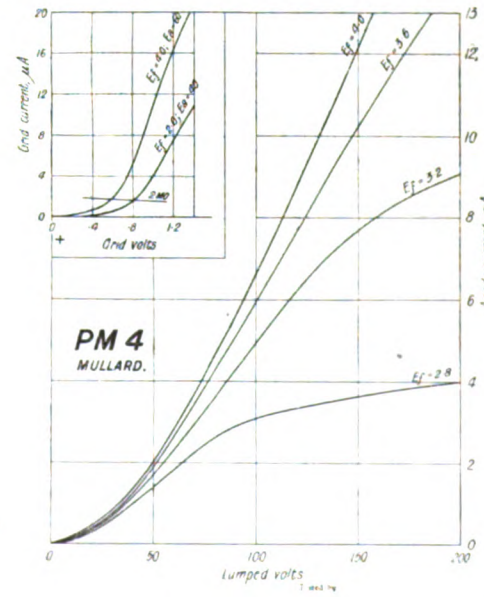
We have recently received a sample of the new type P.V.6. D.E. valve, made by the Edison Swan Electric Co., Ltd.

This differs slightly from the previous model, several improvements, both in construction and characteristics, having been made.

The shape of the anode and grid has been changed from the cylindrical to the oval box type, and the filament is of V pattern. The bulb is pipless and the base is of moulded material.

Fil. Volts. Ef	Fil. Cur. If	Sat. Plate Cur. Is	Anode Imped-ance. Ra	Voltage Ampli. μ	Power Ampli. P $\left(=\frac{1\,000\,\mu^2}{Ra}\right)$	Filament Efficiency. F $\left(=\frac{Is}{\text{Watts.}}\right)$
1.6	.43	8	14 000	4.9	1.7	11.6
1.8	.46	15	8 500	3.3	1.3	18
2.0	.49	36	7 400	3.6	1.75	37
2.2	.52	40	7 000	3.9	3.4	36.5

The filament voltage rating is the same as before, *i.e.*, 1.8-2.0, but the filament current has been increased from 0.4 to 0.5 amp. The impedance and amplification factor have been lowered.



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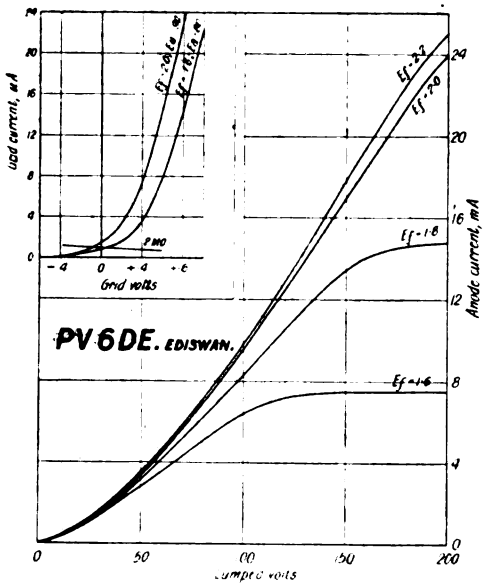
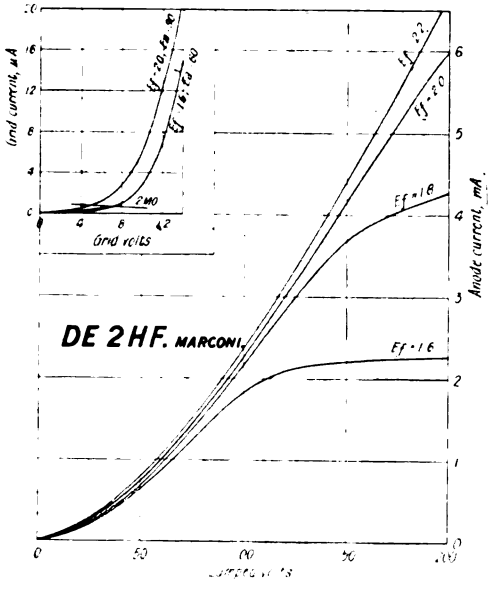


As will be seen from the table, we found the saturation current to be 40mA at 2.2 filament volts, which is ample for large loud-speaker work.

The impedance, rated at 10 000 ohms by the makers, was found, in the case of the sample tested, so be as low as 7 000 ohms at full filament heat. The amplification factor was in the neighbourhood of 4.0.

The valve should be an excellent one for the last L.F. stage, since it can handle a large power. For this purpose the valve should be run at a filament voltage of 2.0 or 2.2 and a lumped voltage of about 140. With a grid-bias of —9 volts, the anode voltage will be about 180. The price is 18s. 6d.



Marconi D.E.2 H.F. and D.E.2 L.F.

These are two valves of similar construction and filament rating, but designed for H.F. and L.F.

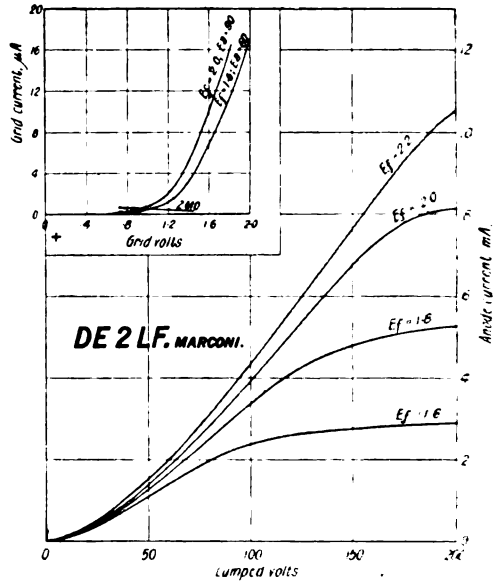
D.E.2 H.F.

Fil. Volts. Ef	Fil. Cur. If	Sat. Plate Cur. Is	Anode Imped-ance. Ra	Voltage Ampli. μ	Power Ampli. P $\left(=\frac{1\,000\mu^2}{Ra}\right)$	Filament Efficiency. F $\left(=\frac{Is}{Watts.}\right)$
1.6	.126	2.5	45 000	9.5	2.0	12.4
1.8	.135	4.75	29 000	8.1	2.3	19.5
2.0	.143	7.5	25 000	8.9	3.2	26.2
2.2	.151	11.0	22 000*	9.3	3.9	33.0

* At 200 V.

work respectively. They are for use with 2-volt accumulators, and come in our "215" class.

The caps are of the new moulded type, the bulb being pipless and slightly tapering. The electrodes are small and cylindrical and arranged vertically.



From our tables, it will be seen that the filament voltage and current are similar in both cases, as are also the saturation current and filament efficiency.

D.E.2 L.F.

Fil. Volts. Ef	Fil. Cur. If	Sat. Plate Cur. Is	Anode Imped-ance. Ra	Voltage Ampli. μ	Power Ampli. P $\left(=\frac{1\,000\mu}{Ra}\right)$	Filament Efficiency. F $\left(=\frac{Is}{Watts.}\right)$
1.6	.128	3	36 000	6.75	1.25	14.6
1.8	.135	5.7	23 500	5.9	1.58	23.4
2.0	.143	9.5	18 500	6.65	2.4	33.0
2.2	.150	12.0	15 000	5.4	2.0	39.5

Between the anode impedance there was not so much difference as would be expected. In the case of the L.F. valve, the impedance could have been made less with advantage.

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The amplification factor, in the case of the H.F. valve, was not so high as was indicated by the makers' rating. Possibly our sample was slightly different in characteristics.

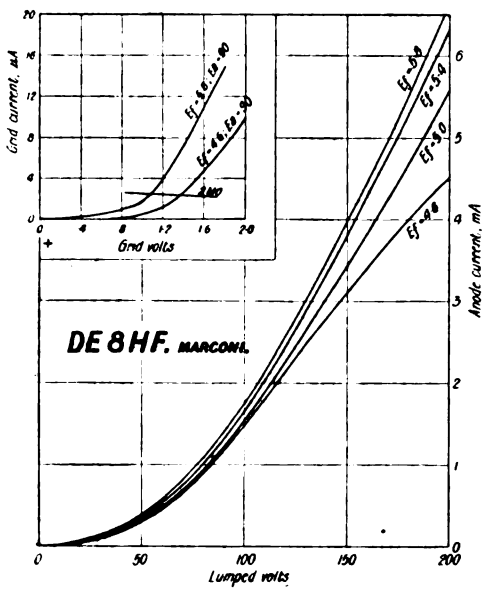
D.E.8 H.F.

Fil. Volts. Ef	Fil. Cur. If	Sat. Plate Cur. Is	Anode Imped-ance. Ra	Voltage Ampli. μ	Power Ampli.* P $\left(=\frac{1\,000\mu^2}{Ra}\right)$	Filament Efficiency. F $\left(=\frac{Is}{\text{Watts.}}\right)$
4.6	.102	6.5	30 000	14	6.3	13.8
5.0	.108	11	24 000*	15.5*	9.9	20.3
5.4	.114	15	20 000*	15.6*	12.0	24.4
5.8	.120	20	18 000*	16.5*	15.0	28.7

* At 200 V.

From the curves it can be seen that the L.F. valve must be run at full filament heat to enable it effectively to deal with any large grid swing. As a detector, with a fairly small leak, say, 1 MO, it should be quite efficient.

The H.F. valve could probably be worked quite efficiently as such with a filament voltage of 1.8 and a lumped voltage of about 110, but for L.F. resistance-coupled work at least 2.0 volt should be used on the filament, with a lumped voltage of 140 or 150.



This valve should also be a good detector, with a 2 MO leak. The price of either type is 15s. 6d.

Marconi D.E.8 H.F. and D.E.8 L.F.

These two valves have the same filament rating, and are intended for H.F. and L.F. work.

They are designed for use with a 6-volt accumulator, and are in the "612" class.

The electrodes are arranged vertically, and are flattened, the filament being V shaped. The cap is of the moulded type, which is now standard.

It will be observed from the tables that the filament ratings and emissions in each case are practically identical. The saturation current of 20mA at 5.8 volts in each case almost puts the

D.E.8 L.F.

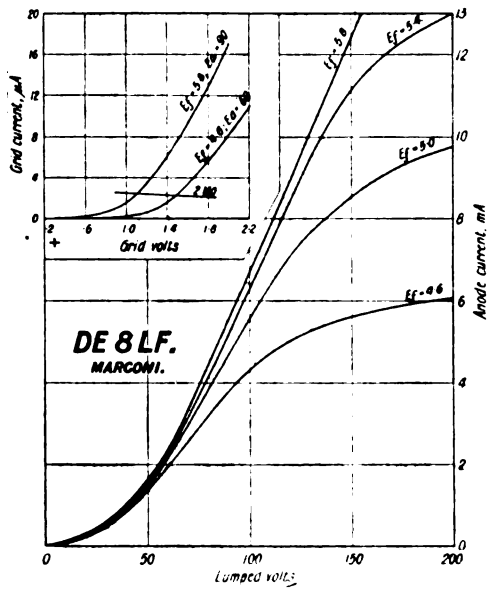
Fil. Volts. Ef	Fil. Cur. If	Sat. Plate Cur. Is	Anode Imped-ance. Ra	Voltage Ampli. μ	Power Ampli. P $\left(=\frac{1\,000\mu^2}{Ra}\right)$	Filament Efficiency. F $\left(=\frac{Is}{\text{Watts.}}\right)$
4.6	.101	6.5	16 000	4.8	1.4	14
5.0	.107	11	13 000	5.5	2.3	20.6
5.4	.112	15	10 000	5.6	3.2	24.8
5.8	.118	20	8 500	6.0	4.2	29.2

valves in the power valve class, and they should perform quite well as power valves.

The L.F. type has a nice low impedance with an amplification factor of about 6 at full filament heat. It will be seen from the curves that at 5.4 or 5.8 filament volts the valve should make an excellent L.F. amplifier. If only used for first stage work, 5.4 filament volts would suffice.

As a detector, the valve is not brilliant, but, of course, it has not been designed for this purpose.

The H.F. type has a very high μ, and comes in the HH. 612 class. Considering this high amplifi-



cation factor, the impedance is quite low, and the valve should prove quite effective both for H.F. and L.F. (resistance coupled) work. It will be observed that the valve does not answer greatly to increased filament heat and 5.4 volts on the filament should prove sufficient.

As a detector, for which purpose it is recommended by the makers, it should give good results. The grid current curve for 5.8 volts on the filament and 90 volts on the anode has a very sharp bend. A 4 MO leak would be suitable.

The price of either H.F. or L.F. type is 22s. 6d.

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The Screening of Small Variable Air Condensers: [R387·1

By D. A. Oliver.

Showing that it is important to take into account the earth effects when it is necessary to know accurately the capacity in a circuit.

MANY perhaps have noticed the deleterious effects of bringing the hand near the unscreened condenser in tuned circuits, or have built into simple wavemeters the ordinary variable condenser without paying much, if any, attention to the important question of shielding, only to discover that the completed instrument resents being moved about to any great extent by promptly changing its reading, to the bewilderment of the operator.

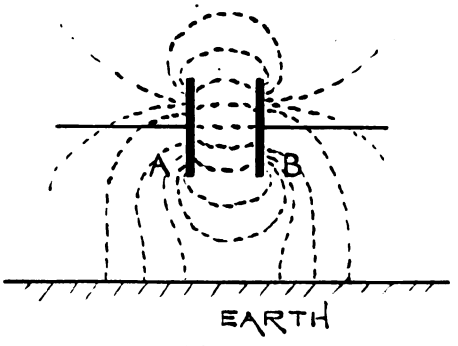

Fig. 1.

Then, again, those who attempt to make quantitative measurements on short wavelengths find it very disconcerting when their tuning condenser settings depend so largely on the proximity of the hand and neighbouring objects, to say nothing of the doubts which arise in the minds of careful workers as to which really is the true capacity reading.

Let us take the case of two sets of condenser plates A and B near earth and at some arbitrary unequal potentials above it.

To follow the usual lines of thought, we must imagine "tubes" or "lines" of electrostatic flux between the plates and between each plate system and earth (Fig. 1).

These tubes have the properties of tending to contract longitudinally and to expand laterally, and if set in motion by means of alternating potentials on the plates, then "capacity currents" will flow between A and B and between A and B separately to earth due to the production of what are called "displacements" in the dielectric medium (in this case air) in which the plates are buried.

The capacities of Fig. 1 can be represented diagrammatically as in Fig. 2 where

(x) = true mutual capacity between A and B.

(y) = true mutual capacity between A and earth.

(z) = true mutual capacity between B and earth.

Now the capacity between any two conductors depends upon the distance between them; in the case of a parallel plate condenser, it varies inversely as the distance.

It will be at once evident that y and z will vary accordingly as A and B are moved nearer to or farther away from "earth" and by "earth" is meant any conducting bodies near the plates.

The effective capacity of the plates between the terminals A, B, for any given values of y and z is

$$\left(x + \frac{yz}{y+z}\right)$$

as y and z are in series themselves and in parallel with x. Thus an unshielded condenser, tested for effective capacity between terminals, has a calibration which is largely indeterminate, as the effective capacity is a function of the position of the instrument relative to "earth."

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It is for this reason that a tuned circuit can be thrown out of resonance merely by bringing the hand near the condenser when unshielded.

The screen serves the purpose of making the capacities y and z in Fig. 1 definite and independent of position, as the screen, if not specially insulated, actually forms part of the "earth."

Let us now examine the three true internal mutual capacities of a condenser. In Fig. 3 let

(A) be capacity between moving plates and fixed plates;

(B) be capacity between moving plates and screen;

(C) be capacity between fixed plates and screen.

It will be evident that A and, to some extent, B and C will depend directly on the setting; B will have a maximum value at the minimum setting of the instrument and will decrease as the moving plates are turned into the fixed ones which shield them, to some extent, from the screen.

C will be nearly constant, provided the moving system revolves entirely within the fixed bank. Some condensers, however, have two extra moving plates fitted, which enable both sides of the two end plates of the fixed set to be utilised. The moving system will then tend to shield the fixed

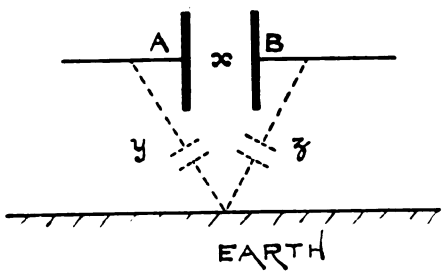

Fig. 2.

plates. In this case B will be practically constant, while C must diminish as the setting increases.

Manufacturers who fit screens to their instruments often engrave them with such statement as the following:—

(i.) "Calibrated with screen connected to moving system."

(ii.) "Calibrated with screen connected to fixed system."

(iii.) "Calibrated with screen earthed" (*i.e.*, not connected to either system).

Let us now consider to what extent these conditions are independent of position and applied voltage.

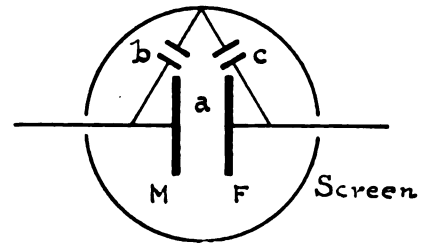

Fig. 3.

In case (i.) capacity b disappears as it is short-circuited and the effective capacity

$$C_i = a + c$$

Case (ii.) is identical, except that c is eliminated and the effective capacity

$$C_{ii} = a + b.$$

Either value is a constant of the instrument and is independent of position and applied voltage, the more usual condition being represented by case (i.).

Case (iii.), however, is capable of two interpretations for a given setting.

(p) The mutual capacity $C_p = a$

(q) The quantity $C_q = a + \frac{bc}{b+c}$

b and c being themselves in series and in parallel with a. Experience shows that the effective capacity given by C_q is the one usually implied.

As has been shown by Mr. Hartshorn (*Journ. Sci. Instruments*, Vol. 1, No. 10, July, 1924, it will suffice to state the result here) the value C_q is a constant only when the current flowing into one bank of plates is exactly equal to that flowing out of the other set. This implies an additional condition, other than the screen being earthed, viz., that the potential relation,

$$b\frac{dV_{MS}}{dt} - c\frac{dV_{SF}}{dt} = 0$$

is satisfied, where V_{MS} and V_{SF} represent the simultaneous potential differences between the moving system and the screen,

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and the fixed system and the screen respectively. The potential condition, in practice, is rarely satisfied and the capacity thus defined becomes a variable.

If the shield is insulated and not connected to either system, the effective capacity between moving and fixed plates becomes somewhat more complicated, and, in addition to the values of the mutual capacities, depends on the potentials of all three conductors. This condition will not be considered here.

Actual Measurement of the Quantities a, b, and c.

If an alternating current bridge is set up, or a method of measuring capacity is available, then, by combinations of connections, we can obtain values for pairs of the quantities a, b, c, and hence effect a separation.

Measure

(1) Capacity between moving plates and fixed plates with screen connected to moving plates.

(2) As before, only screen connected to fixed plates.

(3) Capacity between the screen and moving and fixed plates connected together.

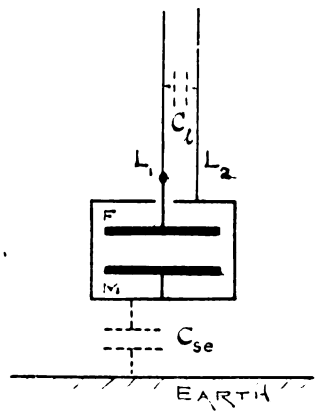

Fig. 4.

Let (1) $=C_1$, (2) $=C_2$, (3) $=C_3$

Then $C_1=a+c$

$C_2=a+b$

$C_3=b+c$

Hence

$a=\frac{1}{2}(C_1+C_2-C_3)=\frac{1}{2}(C_1+C_2+C_3)-C_3$

$b=\frac{1}{2}(C_2+C_3-C_1)=\frac{1}{2}(C_1+C_2+C_3)-C_1$

$c=\frac{1}{2}(C_1+C_3-C_2)=\frac{1}{2}(C_1+C_2+C_3)-C_2$

In the measurements, owing to the limitations of the particular method employed, it may be impossible to keep the screen "earthed" or at zero potential. On the contrary, often the best insulation possible is required, such as that provided by paraffin blocks.

Usually the condenser is connected in parallel with a calibrated variable standard or in an arm of a bridge network. Precision tests then involve readings with the instrument connected and disconnected, the difference being taken up on the standard.

As the screen is insulated, it has a capacity to earth C_{se} (Fig. 4) and therefore should be left in for both measurements, the lead to the fixed system only being disconnected. On disconnecting L_1 (Fig. 5) care should be taken not to alter the configuration of the leads L_1 and L_2 appreciably, or their mutual capacity C_l will be affected. The breaking of the connection has, however, introduced an extra capacity C_t, which is the capacity between L_1 and any unscreened part of the insulated system, such as the terminal, which must, of necessity, protrude. If C be the actual value required for the condenser, then the difference from the measurements referred to above will be actually

$$C-\frac{C.C_t}{C+C_t}.$$

Now C_t in practice is of the order of 0.2 micro-microfarads, while C may be a few hundred, thus the expression reduces to $C-C_t$, so that by a single disconnection it is not possible to measure C, whatever be its value, to a greater accuracy than that determined by C_t. C_t can be made small by having the last few cms. of the lead L_1 of fine wire and by moving it 1 to 2 cms. away from the condenser terminal on disconnection.

In high-frequency measurements, it is desirable to earth the system connected to the screen and to introduce the detector or thermo-heater into the lead on the shielded side, in order to make detector earth-capacity effects negligible. This would hold good, for example, in the case of the ordinary wavemeter circuit used for measurements of effective self-inductance, capacity, self-capacity and effective resistance. Moullin has ably discussed the arrangement

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of circuits in general terms to eliminate earth- and cross-capacity effects, in *World Power*, May, 1925.

Typical Values for the Quantities Discussed.

A number of measurements was made in order that some idea of the magnitudes of the quantities discussed might be obtained.

As a screened laboratory standard variable air condenser of about 1 000 micro-microfarads is commonly found where serious measurements are undertaken, we will take this as our first example.

Case 1.—Using the notation as before, the values for three conditions of setting are given in Table I.

TABLE I.

Condenser Setting.	Frequency.	Capacity: $\mu\mu$F.		
		a	*b*	*c*
Minimum ..	1 000	27	26	30
Half scale ..	1 000	492	24	30
Maximum ..	1 000	1 002	20	30

The screen on the above instrument was square, while the plates were semi-circular. This would account for part of the variation in *b*.

The ordinary capacities for the cases given, (*i.e.*, $a+c$) are 57, 522 and 1 032$\mu\mu$F.

Case 2.—For these detailed experiments, a typical 500$\mu\mu$F semi-circular plate condenser was chosen.

Attempts to calibrate accurately were made as first received, *i.e.*, unshielded. The values were obtained on a capacity bridge by substitution against a well-screened vernier standard condenser "S," and results are recorded for disconnection on both the moving and fixed sides of the instrument. The effect of proximity to the screen of "S" was also investigated.

The values are given to demonstrate the uncertainty of attaining high accuracy of calibration without screens, and the absolute errors as shown above are of much the same order on a condenser of half the range. These become more important as the value diminishes. Thus, on a 200$\mu\mu$F condenser, the accuracy would probably not be greater than 2 per cent. at the maximum, up to about 30 per cent. near the minimum.

The effect the hand produced near the condenser tested was 2—3 $\mu\mu$F.

Case 3.—The instrument of Case 2 was now closely fitted with a cylindrical metallic screen and the three internal capacities separated as described in this article. The frequency was 1 000 cycles, as used throughout.

The results are given in Table 3.

TABLE II.

Condenser Setting.	Frequency.	Remarks.	Capacity: $\mu\mu$F. System Disconnected.	
			Moving.	Fixed.
Minimum	1 000	20 cms. away from shield of "S"	13.3	15.3
Maximum	,,	Ditto	519.5	521.5
Minimum	,,	Close up to shield of "S"	12.0	16.4
Maximum	,,	Ditto	517.1	521.3

TABLE III.

Condenser Setting.	Capacity: $\mu\mu$F.						
	$C_1 = a + c$	$C_2 = a + b$	$C_3 = b + c$	$\frac{1}{2}\Sigma C = \frac{1}{2}(C_1+C_2+C_3)$	$\frac{1}{2}\Sigma C - C_3 = a$	$\frac{1}{2}\Sigma C - C_1 = b$	$\frac{1}{2}\Sigma C - C_2 = c$
Minimum	29.2	42.8	46.7	59.4	12.7	30.2	16.6
Maximum ..	535.2	547.7	45.4	594.4	519.0	29.2	16.7

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The values are representative of the usual wireless condenser fitted with a screen and range 500$\mu\mu$F. The constant *c* is seen to check to 0.1 $\mu\mu$F while *b* diminishes slightly as the moving plates are turned into the fixed ones. It is anticipated that *b* and *c* will not vary greatly

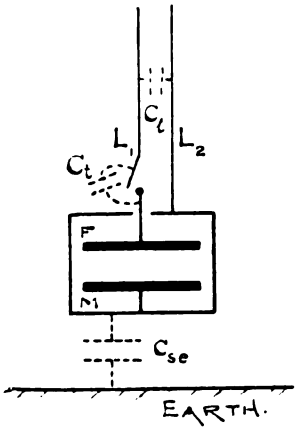

Fig. 5.

with the various sizes of condensers on the market, should they be fitted with screens.

The one and only apparent disadvantage of the screen is its effect in increasing the minimum value. As the screen fitted for the measurements of Case 3 was a good fit on the body of the instrument, but, of course, insulated from it, the increase in the minimum value—about 15$\mu\mu$F—due to calibrating with the moving plates connected to screen, probably represents about the maximum increase likely to be met with for this size of condenser. It is anticipated that the increment would decrease only very slightly for a 250$\mu\mu$F condenser, and *vice versa* for one of, say, 1 000$\mu\mu$F value.

It must be realised that no screening is absolutely perfect, but the uncertainty can be made negligibly small by careful attention to detail, and by allowing to protrude outside of the screen no more than is absolutely necessary of that system not connected to it.

For this reason, amongst others, the fixed system is usually insulated on account of the difficulty of screening the bearing and spindle. The insulation of the latter also presents difficulty, and if carried out efficiently, puts up the manufacturing cost of the instrument.

It is urged therefore that condensers should be provided with screens to avoid outside disturbing influences and stray electrostatic couplings, and to make the capacity calibration independent of position and potential by connecting one system to the shield or screen, and calibrating under this condition. The point raised as to single disconnection on the insulated side should also be borne in mind whether the screen is earthed or insulated.

In conclusion, it is hoped that what has been written will help those desiring accuracy and refinement to attain their object, at any rate so far as the condenser is concerned.

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MICA:

A Lecture to the Radio Society of Great Britain.

By P. R. Coursey, B.Sc. **[R281·38**

[*We regret that owing to the large number of slides used by Mr. Coursey—there were over 70—it has been impossible to reproduce more than a small representative selection.*]

AN ordinary meeting was held at the Institution of Electrical Engineers on Wednesday, 28th October, Brig.-Gen. Sir H. C. Holden presiding.

The minutes of the previous meeting were taken as read and confirmed.

The CHAIRMAN: The lecture to-night is by Mr. Coursey, who hardly requires any introduction, seeing that he is our Hon. Secretary. He is going to tell us all about mica, and I am sure his lecture will be most interesting.

Mr. COURSEY: Not only for radio purposes but for many general electrical uses as well, mica is an extremely important material. It may indeed be said that to-day every unit of electrical energy that is used has involved the employment of mica in one form or another in its generation and distribution. It is equally true to say that very many modern applications and developments of radio communication are just as dependent upon this material. If mica had never been discovered it is probable that other materials would have been used in its place, but its great superiority over many other electrical insulating materials for certain purposes, has led to its very extended use. Mica and micanite are both used in the insulation of electrical machinery generally and mica is used in radio work as a dielectric in electrical condensers.

The subject is one obviously which is not radio in the sense in which one may describe many of the lectures which are given before this Society. Nevertheless I hope that some of the slides which I have to show you—because my lecture will consist mostly of slides and telling you a few things about them—may be of some interest as illustrating some of the things which are used in commercial apparatus and the ways in which these materials are produced.

Mica is a very general name covering many different varieties of material. Primarily the name is typical of compounds consisting mainly of aluminium silicate, which may be combined with various other materials in varying proportions. There are in general two main classes or groups of mica, one which may be referred to as alkali micas, and the other, those containing magnesium or ferro-magnesian compounds in addition to the aluminium silicate base. The mineral Muscovite may be cited as representative of the alkaline class, whilst Biotite is representative of the second group, or ferro-magnesian class.

In the first group are contained most of the clear and lighter coloured micas which are of the most commercial use and have the greatest electrical utility. The second class contains the brown and dark coloured micas.

The commercial sources of mica are mainly India, the U.S.A. and Brazil. Some comes from Canada and Africa, but for many purposes the Indian mica is the only one which is of particular value. The Indian mica is practically all of the Muscovite class, *i.e.*, the alkaline mica and contains an alkaline base, such as potassium or sodium, in addition to aluminium. In India generally the micas, which come from the neighbourhood of Bengal, are mostly ruby in colour, whilst those from the Madras region are of a greenish colour. The term Muscovite has some connection, I believe, with windows, because at one time there was a trade in this material for window panes and for portholes of Russian men-of-war. It consequently was called Muscovy glass.

In the old days, I mean 50 years ago, mica was produced in a very primitive manner as compared with modern mining methods. The methods then employed involved only very shallow working, practically only scratching the surface where the material might be found on or near

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the surface. These methods have been greatly improved upon in modern times, and the history of mica mining in India has gone through several stages. As I indicated just now, the Indian mica is one of those which has particular importance for many electrical purposes, and the slides I am going to show you are concerned mostly with the production of Indian mica.

It may perhaps interest some of you to have the formula for this material. Its composition is somewhat indefinite and the different classes of mica differ very considerably in composition. The general type of formula, however is :—

$$H_2KAl_3(SiO_4)_3$$

That is typical of the constitution of the alkaline class. Another alkali mica has potassium replaced by sodium :—

$$H_2N_aAl_3(SiO_4)_3.$$

The ferro-magnesian or magnesian micas have a very complex structure. Some of them are dark in colour, but there is still some alkali element in the constitution of the material. A general formula is :—

$$(HK)_2(MgFe)_3(AlFe)_2(SiO_4)_3.$$

That material is obviously rather complex and it is not a simple salt.

Another one of the same class may be written as follows :—

$$[HK(M_gF_e)]_3M_g.Al(SiO_4)_3$$

The chemical analysis of the different classes shows up the difference between the compositions. Taking Muscovite as representing one class and a representative of the darker mica for the second, the silica content is practically 48 per cent. in Muscovite and 43 per cent. in the dark mica ; aluminia is 30 per cent. and 19 per cent. respectively ; ferric oxide is 2½ per cent. and 17½ per cent. respectively ; lime is 0.9 per cent. and 1.8 per cent. respectively ; whilst the potassium is 10 per cent. and 8 per cent. respectively. The main difference is in the iron content which is 17 per cent. in the dark mica as against 2½ per cent. in the Muscovite. The other materials, lime, potassium, sodium, etc., are in similar proportions. Typical analyses are set out in the following table:

	Muscovite.	Dark Mica.
Silica (SiO_2)	47·95	43·42
Alumina (Al_2O_3) ..	30·26	19·00
Ferric Oxide ($F_{e_2}O_3$)	2·43	17·64
Ferrous Oxide (F_eO)	3·10	—
Magnesia (M_gO) ..	0·94	0·54
Lime (C_aO)	0·98	1·81
Sodium Oxide ($N_{a_2}O$)	2·00	3·66
Potassium Oxide(K_2O)	10·19	8·77
Water	1·13	4·30

Mica is a crystal ; probably many of you have seen pieces of mica in its raw state at one time or another, and there are a few samples here to-night to illustrate the different appearances which this material may have. It crystallises in what is known as the monoclinic system, but its crystal form is not perfect. The chief characteristic of mica from the crystalline point of view is its perfect basal cleavage over large planes. The pieces of mica which are shown here can all be split down into many layers, and out of the larger pieces of mica, as it occurs in nature, it is easy to pull off flakes, whilst if a suitable knife is used to part the flakes it is possible to separate them into very thin laminæ. Some of these are less than 1/1 000 inch in thickness, although obviously the thinner the laminæ the greater the difficulty in splitting a clear lamina without fracture.

The different micas have very different colours and by holding them in front of the lamp it is possible to see how different the colouring is. People often wonder why a mica is called ruby mica, because in thin layers it is difficult to appreciate that it is ruby, but if a piece of the original thick mica is placed in front of the lamp it may be seen that it is obviously ruby in colour, although the thin flakes seem clear, with, if anything, a brownish tinge. Some mica has a greenish colour, but it is the clear and the ruby mica which has the greatest commercial importance for radio purposes, and for insulation material for high frequency work or for fitting into condensers. Sometimes one finds mica which is stained with a number of red and black spots all over the material. These specks are of different composition, being very frequently iron or iron oxide, and from an electrical point of view such mica has great disadvantages.

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Most of the commercial use of mica involves comparatively small pieces and the larger pieces of mica are much more rare. Pieces several feet across are not nearly so common as the smaller pieces, although pieces up to several feet across do occur. Mr. Elwell has kindly brought for me a very thin lamina of mica about 1 ft. across, which gives an idea of the size it is possible to split mica into, this piece being about 1/1 000 in. thick. The extraordinary strength of these crystalline cleavages is rather remarkable, considering that it is possible to split off laminae like that without breaking.

The cost nowadays is rather prohibitive for the large sizes of mica sheet, the price per unit weight going up very rapidly as the size increases.

In India mica mining has gone through three main stages. About 50 years ago the mica field property was rented to a few people who paid rent direct to the Government and, as I said just now, the mica was mined mostly on the surface and in very shallow workings. That work was very haphazard. People got the mica when they wanted it and there was no particular supervision of the work or any particular control of how it was carried out.

In the second period the Indian Government auctioned the existing mines at a rental per year, so that each man tried to get out as much mica as he could in that time, and did not care about the property so long as he got out the maximum amount of mica possible.

The result was that the mining was done very hurriedly, no particular care being taken to prepare plans of the mine workings or to strengthen the workings structurally to prevent their collapse. Consequently the mines rapidly went to ruin under that treatment and, furthermore, no records were kept as to where mica had been dug out. The result is that to-day some of the old workings are come across accidentally because their positions were not known.

There is no indication very often on the surface or even below ground of the position of the mica veins. Very frequently searches go on underground for quite a long time to discover the veins, but without any success. An instance of this occurred in connection with a mine called the Bent Mica Mine. It was a disused mine and the exact locality of the underground workings had been lost. The mine was re-opened by new shafts which had been sunk vertically on the modern method.

Two of these shafts were sunk 300 feet deep and modern pumping plant was put in. The search went on underground for about 2½ years before the mica vein which was known to exist in that locality was rediscovered.

In these old workings very primitive methods of mining were sometimes carried on. There was no adequate machinery for lifting the debris, water, etc., from the mine, and it was customary to arrange rows of ladders and get lines of women and children to pass trays of the debris, water, broken rock, mud, etc., from the underground workings up to the service. These women and children were in two lines passing the trays up one way and down the other and as many as 300 people had been employed in chains of ladders in this way, a very laborious and obviously very primitive process, and not conducive to rapid production.

Illustrating the primitive method (described above) by which the debris, etc., was removed from the mica mines of India.

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The third and modern period of mica mining development in India is the one in which vertical shafts with machinery, frequently with electric light as well, is adopted, the result of this much more scientific mining, of course, being very greatly increased production.

Mica mines in India now are usually partitioned up by the Government into definite regular squares, separated by clearings to divide the squares which are approximately 40 acres each in extent. The clearings may be about 20 ft. wide and the lines are laid out in a chess board pattern north, south, east and west. Some of these clearings are practically roads through the jungle.

Hand-drilling in a mica mine.

Showing the curious shapes of the mica as it is brought from the mine.

Many of the new mines have electric light throughout and where electricity is available it is used for hauling, pumping, etc. In others steam haulage is used with candles as the illuminant below ground. Some of these modern mines extend a distance of 500 ft. below ground level.

One illustration shows the method of drilling the rock face and blasting it out with dynamite. The hand method is found much more practical than machine drilling and the reason apparently is, that the natives get used to the feel of what the drill is going into and they can feel when they are getting contact with the mica, and so can prevent going through the mica crystals which a mechanically driven drill would not be able to detect. Therefore, the hand method is largely in use and is found much more successful than machine drills.

The rough mica got out below ground is hauled to the surface and tied up into bundles for storing and subsequent treatment.

The material is very dirty and the method of cleaning it is by cutting the edges of it with a peculiarly shaped sort of sickle knife with which the edges are trimmed and the bits of dirt, stone and other foreign material is removed. That accounts for the extraordinary shapes of the rough mica pieces when they come over here.

The rough block mica reaches us mostly in roughly shaped pieces a few inches in dimensions, and being usually something less than $\frac{1}{4}$ in. in thickness. These roughly shaped pieces are then sorted out to size and graded into different qualities, because the different sizes and grades obviously fetch varying prices in the London market. Finally it is packed in boxes ready for despatch to the railway for conveyance to London.

The lecture concluded with a long series of slides illustrating a tour through a Bengal mica mining area, together with pictures of work being carried on with mica for building condensers in the Dubilier Condenser Company's factory.

The Discussion.

The CHAIRMAN: It is now my pleasant duty to call upon somebody to open the discussion. I quite appreciate that the subject Mr. Coursey has dealt with, and the manner in which he has dealt with it, does not lend itself very much to discussion. That is unfortunate, but no doubt some members of the audience will like to ask some questions even if we do not have a regular discussion. (After a pause.) It appears rather that the audience is a little bit afraid of asking any

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questions, but there are one or two which I should like to ask. The first is, to what extent does the electrical conductivity of mica mined in one mine vary from that mined in another? It is affected very much, I believe, by iron.

Mr. COURSEY: Yes, that spoils it for many electrical purposes.

The CHAIRMAN: Do you get good and bad samples from the same mine, so that you get from the same mine, mica which can and mica which cannot be used for condensers?

Mr. COURSEY: Yes, there is an enormous variation in the quality of mica obtained from the same spot in a mine.

The CHAIRMAN: There is another question which is more curiosity than anything else. What is the thinnest sheet of mica that can be obtained? You spoke of 1 oooth inch, but can it be split to a thinner sheet than that?

Mr. COURSEY: It can be split thinner than that, but I am not sure of the limit. The crystalline structure permits of almost indefinite cleavage, but the difficulty is mechanical more than anything else.

The CHAIRMAN: How do they manage to split it? I take it that it has to be split within limits and that therefore it requires a good deal of skill and, I take it, a certain amount of measurement afterwards.

Mr. COURSEY: It requires measurement afterwards and it certainly requires skill in splitting. It is easy enough to split pieces off, but it is not easy to split off flakes of a given thickness. That only comes by experience in that particular work and some people can do what others cannot. It is mostly a matter of skill in handling the knife to make the first incision. When it is used for building condensers, it all has to be measured afterwards and sorted into different thicknesses. I do not profess to be a geologist or a chemist and so cannot tell you very much more about the structure of material.

Mr. FOGARTY: I am sure you will all endorse me when I say that we owe a very hearty vote of thanks to Mr. Coursey for his very interesting lecture. As he says, it does not perhaps seem directly applicable to radio, but, after all, as the Chairman has said, mica is of very great importance and, in fact, in radio we would be very badly off without it. My own recollection goes back to the time when mica condensers of various qualities were not available and in those days we had to use glass or metal plates strung up in air and, as you know, mica condensers were not made in anything like large quantities nor were they very satisfactory until the whole art of applying mica to condenser manufacture was studied by Dubilier, who was one of the principal workers in that direction. Therefore we really do depend upon mica very largely, not only in radio but in the electrical engineering industry generally. There is one particular point upon which I should like a little information, if Mr. Coursey can give it to me, and that is this. If one takes a sheet of mica and brings two metal surfaces in contact with it on either side, one obtains a condenser of a certain capacity, but the capacity seems to change, not altogether proportionately, but it can be changed by pressing the two metal plates into contact with the mica up to a certain point. It seems that the capacity can be varied in that way. Another point is that if you take a piece of mica and lay two pieces of tin-foil against it, you do not seem to get a maximum effect. In other words, the capacity is smaller, but if you moisten the surfaces of the metal with shellac varnish or some other varnish, and then put them in contact with the mica, you get a very efficient condenser; you get a larger capacity. Can Mr. Coursey tell us why that is? I now ask you to give Mr. Coursey a very hearty vote of thanks.

Mr. REEVES: I have great pleasure in seconding the proposal. I am sure we have all listened with very great pleasure to the lecture.

The vote of thanks was given with acclamation.

Mr. COURSEY: I thank you very much for the kind way in which you have received the lecture. With regard to Mr. Fogarty's query, when a sheet of mica is placed between two metal plates, there is a layer of air between the metal and the mica, and air has a dielectric constant of 1, whereas mica has a dielectric constant of about 8. Therefore, obviously, as you reduce the amount of air by pressure, the effective dielectric constant of the mixture rises from something in the neighbourhood of 1 when the mica is direct from the metal, to something in the neighbourhood of 8 when they are closely touching. When the metal is moistened, the air is replaced by something else having a higher dielectric constant. Obviously the resultant dielectric constant and the capacity rise. I think that is really what happens when the mica is stuck on with shellac.

The CHAIRMAN announced the election of 7 new members.

Precision work at Messrs. Dubilier's factory — measuring the thickness of small sheets.

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Long-Distance Work.

By Hugh N. Ryan (5BV). **[R545·009·2**

WE have now arrived at the time of the year which we have come to regard as the beginning of the real DX season. This year, however, the work has gone on so well during the summer that the winter will have to produce some very startling results indeed if it is to retain its accustomed place in the experimenter's calendar. Indeed, such results as have been obtained so far would seem to suggest that summer conditions are actually better than those of winter for the wave-lengths now in general use. However, one remembers that in previous years very good winters have sometimes been immediately preceded by brief spells of bad conditions, and history may repeat itself this year.

This seasonal variation of DX conditions is closely related to the general question of the connection between weather and range of signals, which question is at present occupying the attention of quite a number of experimenters. The summer did not provide a very wide range of weather this year, and so the greater changes which occur about this time of the year should provide those interested with some very useful data supplementary to that which they obtained during the summer, and (perhaps) checking up with any theories which they may have evolved from their earlier observations. At all events, those working on this subject should, by the middle of December, have had time to collect fairly complete data, and so I propose to give, in the next report, a summary of all observations reported to me, together with any theories the observers have deduced from them. I already have quite a number of such reports, and I hope everyone concerned will let me have any results they care to publish in time for next month's issue.

It would be interesting to know whether anybody has been making systematic observations upon the distribution of intelligible telephony upon 20- and 40-metre waves. Even when telephony from a given station is always audible at another given station, its intelligibility always varies greatly at different times of the day, and also the telephony of any station varies with the distance of the listening station. A station may sound like slightly mushy sustained C.W. at ranges up to 50 miles, be inaudible up to a thousand miles or so, and produce perfect, undistorted telephony at the Antipodes. Ten minutes later the same station's phone may be perfect at short ranges and sound like 25-cycle A.C. C.W. at 12 000 miles. The phenomena experienced are altogether too involved to be explained by guesswork (though I have heard some pretty wild guesses), but systematic observations might be interpreted into a solution.

In connection with observations at various distances, it is, I think, to be deplored that so little work is now done with the nearer countries. It is something of an anomaly that we can work daily with the ends of the earth, but cannot at all readily work with other stations in Europe—not because we are unable to do so, but because we have got into the habit of not listening for any station less than a few thousand miles away, and not answering one under about six thousand. Working over great distances may be more exciting, but we have had time to get over the excitement now, and we shall not solve the many problems of short waves by collecting all our data at one end of the scale and ignoring the other. Let us get QSO Europe again, and meet again the men we used to enjoy working a few years ago. It will probably not be so very easy, and will, I think, provide more interest than the routine daily working of A's and Z's exclusively. After all, the A's and Z's work each other, so do the U's and the Continental stations, but how often do we?

Britain is at last in touch with Western America, which has hitherto been out of our range for two-way work. We are still far from being in regular touch with that part of the world, but G2SZ has worked U6VC and U6CTO. FB,OM! 2SZ has also got phone through to the States, Australia, New Zealand and India.

5BV has been "off the air" all the month.

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6YK has now come down to 45 metres, with slightly greater power, and has worked all Europe on this wave, both by day and night, but finds the daylight work easier.

Mr. Guy, of Pinner, has been doing some more good work with the receiver this month, his log including twenty-three A's and Z's. In common with many others engaged in intensive reception, he reports that calls heard in the mornings are steadily decreasing, and those heard in the evening increasing.

6VP, after several months of very good work on the longer waves, has now started up on 45 metres. Results in daylight are greatly improved by the change, but no results at all have been obtained at night. He wants to know whether low-power short-wave signals get anywhere at all at night. (So do lots of us, OM! They certainly don't seem to.)

Mr. Erith, of Sutton, is continuing his very methodical observations on signal strength and weather conditions, and there will be more about his results in next month's summary. He has a fine bag of South Americans this month.

Stations in the Eastern Counties would appear to have passed a less active month than usual, 2LZ and 5QV having done most of the work, both being QSO most of the world, while 2TO has added Russia to his list of countries worked.

2AO has recently worked several Australians in the evenings. It seems certain that our signals now get to Australia better in the evenings than in the mornings, while the number of A's reported here in the evenings increases steadily.

5AX has been doing little transmitting, but quite a lot of receiving. His log this month includes an American "six" and "seven" and a Canadian "four." 2KK also has a good log of distant stations received during the month.

2NB has worked BER, a station in Bermuda being the first British station to work this country. Besides this work on the 40-metre band, 2NB is transmitting on 9.2 metres every Thursday at 23.30 G.M.T. and every Sunday at 11.00 G.M.T., and would be glad of reports.

A damaged hand has kept 5MO off the air, but the cessation of transmitting has given him plenty of time for receiving, though under difficult operating conditions. His most interesting log entries are three new South Africans, OA3E, OA4L, and OA4V, in addition to our old friend OA4Z. (By the way, the South African call-signs were misprinted last month. O4F and O4Z should, of course, have been OA4F and OA4Z). 5MO also reports a good number of Argentines.

5NJ (near Belfast) has now got a generator working, and has been QSO several Australians, all of whom report strong signals. I have had no reports from either Scotland or Wales this month.

Before going on to foreign work, I should like to mention the visitors at present with us in London—NPCTT and NOAW (respectively president and traffic manager of the Dutch section of the I.A.R.U.) and A2BJ. We extend to them a "Ham welcome."

The Spanish stations are now going well ahead with DX. EAR1 has been heard in Australia with 90 watts. EAR2 is just returning to the work after having been inactive all the summer, and will soon be going with considerable power. EAR9 is working the United States nightly with 90 watts. EAR10, on 80 metres, has reached Paris with 30-watt phone. EAR22 has started working Americans with 50 watts.

A number of Swedish stations are now QSO Australia and New Zealand, with really small power. SMTN is in regular communication with Australia with 18 watts and has worked with only 3 watts. SMWF and SMXU often work New Zealand. SMZS's owner has practically given up DX chasing, and is working on signal strength measurement, but his second operator is still working the station.

Most of the Italian stations are now on about 40 metres. I1ER has led most of the DX work, and was the first Italian to work New Zealand. His signals are also reported to be the best heard in America. I1MT, I1NO, I1RG and I1AF have worked New Zealand, while I1AS has worked 17 Z's with only 15 watts input.

I hope to have more foreign reports next month. I thank those foreign amateurs who have sent me reports, and would be glad to have news from France and Belgium.

Please let me have all reports by the 10th of each month.

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Rectifiers for High-Tension Supply.

By R. Mines, B.Sc. **[R355 5**

Addition to Part IV.

Arc Rectification at Atmospheric Pressure.*

Dunoyer and Toulon† state that "polarisation" of the arc is more easily obtained when it is long, for then the metal anode, which must be relatively cool, is further removed from the hot cathode. They succeeded in obtaining stable rectification by using an auxiliary "maintenance" arc, running on D.C. between carbon electrodes, the rectifying arc playing between the cathode of the maintenance arc and a water-cooled anode lowered into the flame of the arc after it had been struck.

The maintenance arc was also successfully run on A.C.; with this arrangement multiple anodes were tried. Four water-cooled copper tubes arranged symmetrically around the auxiliary arc (whose axis was vertical) were connected in cyclic order to the four-phase secondary of a transformer (or a two-phase one with mid-point tappings); the rectified output was drawn from the star point (negative) and the auxiliary arc circuit (positive). Trouble was experienced from shorting between adjacent anodes, through the conducting vapour of the arc.

* E.W. & W.E., Vol 2, p. 899, Nov., 1925.
† *Journ. de Physique*, Vol. 3, p. 389, Nov., 1922.

Part V—Vacuum Discharge Rectifiers.

I.—Effect of Rarefying the Gas.

OUR preceding articles have described how a gas and atmospheric pressure is capable of conducting electricity, and how this conduction can be utilised for rectification purposes with suitable arrangements. Nevertheless, the conductive condition cannot be established without the application of a high electric stress, and this is a distinct disadvantage, because in the case of a rectifier this means a high drop of potential in the rectifier in the conductive direction, involving a loss of power large in proportion.

It has been shown also that, according to the Kinetic Theory of Gases, every molecule is in motion, moving a certain distance, colliding with another, rebounding and moving away, colliding again, and so on. It is possible to determine the average distance travelled between collisions (averaged over the motion of any molecule and averaged for all the molecules); it is called the "Mean Free Path" of the molecule. By similar argument, when an ion is moving along a potential gradient, the average distance it travels between successive collisions is called its mean free path. The value of this quantity is dependent upon the nature of the molecule (kind of matter) or the nature of the ion; and upon the physical state of the gas (its pressure and temperature).

It would appear obvious from these considerations (and it is, in fact, borne out by experiment) that one may exert a certain amount of control over the mean free path. Thus if the pressure of the gas is reduced, its density becomes less, there are fewer molecules present in unit volume, and the mean free path is increased.

There is also a secondary effect which is nevertheless important—at normal pressures electrons tend to collect around themselves neutral molecules (actually these condense on the electrons as nuclei), and only under the influence of high temperature or of high electric stress do they become freed from this burden and show their inherent mobility; whereas, under reduced pressure, the negative ions are usually free electrons, remaining so even in weak electric fields.

II.—The "Geissler" Discharges.

These two factors wreak a profound change in the manner in which a gas will conduct electricity. Thus the first reduction of pressure of the air in which a spark discharge is taking place causes a drop in the

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P.D. required to pass the spark ; also the spark becomes quieter and is soon replaced by sinuous streamers, showing that the conduction is approaching nearer to a condition of regularity.

When the pressure has passed about 1/100 of its original value the air is highly conducting ; the preceding visible discharge has disappeared but there is an intense glow of light over each electrode, indicating the regions where ionisation is taking place. Townsend calls this the "first type" of Geissler Discharge.

With further decreasing pressure, these glows expand and take on beautiful forms and colours, depending on the shape and disposition of the electrodes, and also on the gases present. These succeeding forms of the vacuum glow discharge do not help our present subject, so the reader is referred to the text-books for detailed descriptions of them. We shall have occasion, however, in a later section to describe the "fourth type" and the conduction mechanism underlying it, and the "cathode ray" discharge.

III.—The Neon Tube Rectifier.

It has been found that when only a small current is passed through the discharge tube (the gas pressure being appropriate to the first type of discharge) the glow on the cathode may cover only a portion of its surface ; under this condition, the fall of potential near the cathode is approximately constant, not dependent upon the current flowing. But as soon as the electrode is wholly enveloped, the potential fall increases with increase of current. These phenomena do not take place to the same extent at the anode ; hence it is possible to produce an asymmetric conductor, or rectifier, by making the two electrodes of unequal areas.

Then if an alternating P.D. is applied to such an apparatus, and its value chosen appropriately, the discharge may be adjusted to the condition of "constant cathode fall" with the larger electrode as cathode, while in the reverse direction the cathode fall (taking place at the smaller electrode) becomes greater due to the higher current density at its surface. The result is that the current wave flowing through the device is not symmetrical—partial rectification is obtained. The "rectification ratio" (defined as the ratio of the mean currents flowing during the two half-cycles) is of the same order as the ratio of the electrode areas.

It is to be noted that if too small an alternating P.D. is used, or too little current drawn from the output terminals when the device is used in a rectifying circuit, the discharge may assume the "constant cathode fall" condition in both directions. In this event there will be no asymmetry in the conductance of the tube and hence no rectification. Similarly, if the apparatus is loaded excessively, the current density will rise above this condition at both the electrodes ; the discharge will again tend to become symmetrical and the "rectification ratio" to approach unity.

The "Osglim" type of Neon lamp lends itself moderately well to use in this manner due to the disparity of size of its electrodes ; but a more practical form for the apparatus is a tubular glass bulb, containing a metal cylinder and a concentric metal rod of small diameter as the electrodes (see Fig. 1). The bulb is exhausted and then filled with Neon to a pressure a little over 1/100 of an atmosphere—Neon being chosen because it "conducts" more easily than other gases ; by this is meant that the P.D. at which conduction commences is much lower.

IV.—Properties of the Neon Rectifier.

The first point to notice about the glow discharge in such a rectifier is that the conduction will not take place until the applied P.D. rises above a certain value, called the "striking P.D." and similarly when the P.D. falls below approximately the same value (usually a little lower than the striking point) the glow extinguishes itself. The value attained in the modern Neon tube lies between 140 and 170 volts.

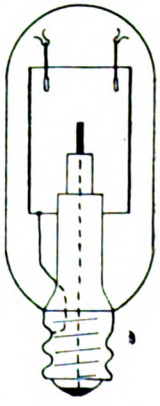

Fig. 1.
Neon rectifier tube.

Another feature of the Neon tube is its "flat" characteristic, rendering it unstable to almost the same extent as the spark and arc discharges, which have negative characteristics. Hence, unless the circuits in which the tube is used contain means for limiting the current (the load receiving the

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rectified current will sometimes act thus), it is necessary to connect in series with it a stabilising resistance. (The value of this is a few thousand ohms for a small Neon lamp connected direct to the mains—it is wound in the lamp cap—but need not be so high for rectifier tubes which carry much heavier currents.)

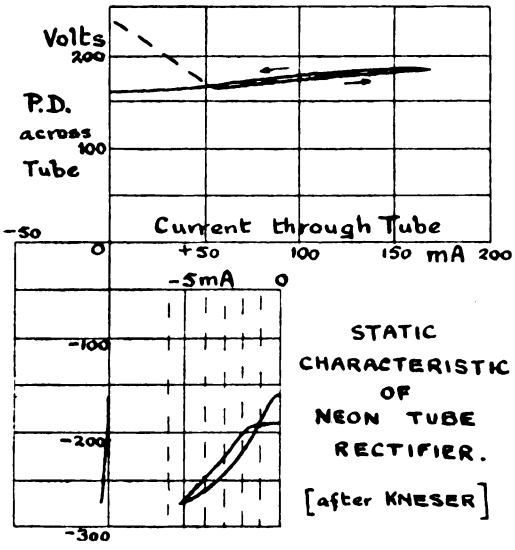

Fig. 2.

The P.D.-current characteristics of a typical rectifying tube (containing a mixture of helium and neon) are shown in Figs. 2 and 3. From the latter is will be seen that when the alternating P.D. only just passes the striking point, the valve action is reversed in direction—this is a condition which it is important to avoid when a reservoir condenser is used on the D.C. output.

Thus, unless a stabilising resistance is used which is absurdly high, the potential drop in the rectifier will not rise much above the striking value, and it is this drop which determines the power lost in the rectifier. We see immediately that there is an immense difference in this respect between the vacuum type of rectifier and the atmospheric types that we have previously described.

Fig. 4, which is reproduced from an oscillogram given by Kneser* shows the waveform of the current flowing through a rectifier of this type into a non-reactive load. It will be noticed that in this case there is no back E.M.F. in the circuit receiving the rectified power; for, when no current is flowing, the whole of the supply P.D. comes across the rectifier, and it is when this attains the striking point that the current suddenly commences, ceasing again when the P.D. falls past the extinction point. These conditions hold for both half-cycles of the wave; but the degree of inequality between the positive and the negative current pulses show a very satisfactory rectification ratio.

V.—Effect of a Steady Back E.M.F.

It is agreed that the wireless experimenter requires essentially a steady high tension on his apparatus; it is important to consider the effect of supplying this with a vacuum discharge rectifier, such as the Neon tube described above. The high-tension power has to be pumped against a steady back E.M.F., and the effect of this condition on the P.D. and current waves is shown in Fig. 5. It will be seen that no current can flow in the positive direction until the alternative P.D. supplied to the apparatus reaches a value $E + e$, where e is the steady

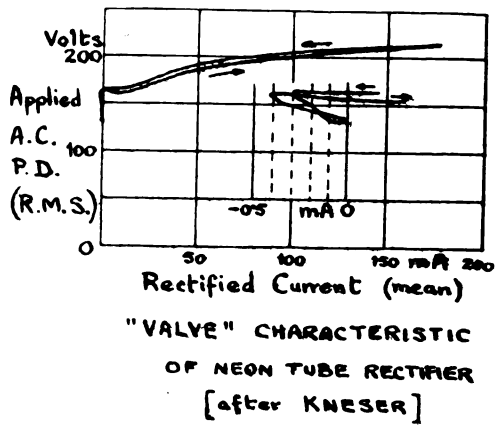

Fig. 3.

back E.M.F., and e is the striking P.D. of the rectifier tube; because it is not till then that the potential drop across the rectifier becomes equal to the striking P.D. The immediate effect of this is a considerable reduction in the duration of the pulse of positive current. Conversely, the glow discharge becomes established whenever the supply P.D. falls below (algebraically) the value $E - e$. Evidently then e should be less in value than E (as it should be if the

* *Ann. der Physik*, Vol. 72, p. 519, Nov., 1923.

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proportion of power lost in the rectifier is to be kept reasonably small) which means that the inverse current will be flowing for more than half of the cycle.

Thus, even should there be no increase in the maximum value of the inverse current as a result of the high peak of reverse P.D. applied to the rectifier, the quantity of electricity passed during the inverse pulse is considerably increased. A point is soon reached, in fact, where it becomes equal to the positive pulse of electricity, and here

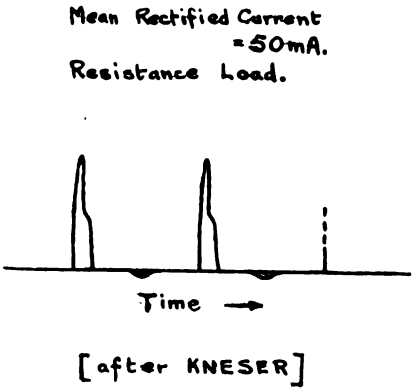

Fig. 4. *Oscillogram showing current wave through Neon rectifier.*

obviously all rectification effect ceases. Beyond this point the D.C. circuit would begin pumping power into the A.C. circuit, should it be capable of so doing !

The importance of using perfect rectifiers for wireless work is apparent.

VI.—Limitations of the Glow Discharge Rectifier.

It has been stated that, with the type of discharge tube described above, the ratio of the maximum currents passed in the two directions is of the same order as the ratio of the surface areas of the electrodes. There are obvious limits to the magnitude of this ratio obtainable, imposed not only by constructional considerations but also by heating ; for if the small electrode is made too small, the surface density of the energy dissipation due to positive ion bombardment rises too high, resulting in overheating of the electrode. In general, this will give trouble due to evolution of gas from the electrode, upsetting the discharge conditions in the rectifier; but should this difficulty be overcome by use of suitable material for and "degassing" of the electrode, care has still to be taken that its temperature shall not rise sufficiently to cause thermionic emission, for then conduction will take place when this electrode becomes negative, and with this polarity the tube is supposed to be non-conductive.

VII.—The Positive Space-Charge.

Given then that the electrodes are cold, the supply of electrons is due mainly to the bombardment of the cathode surface by positive ions, just as is the case with heavy discharges at higher gas pressures. The electrons in turn ionise the gas, thus maintaining the supply of positive ions. There are present then ions of both signs in the conducting gas ; but the negative ions being free electrons, show a very much higher mobility under an electric field, and as a result they move along the potential

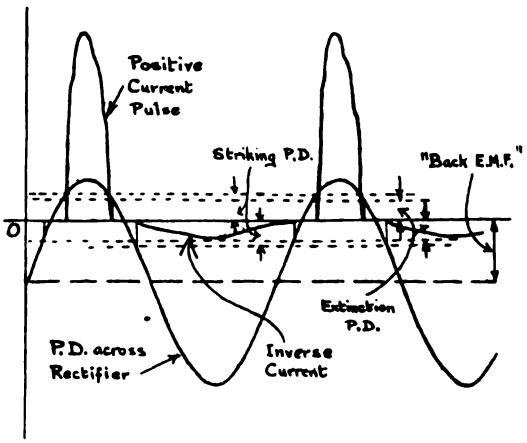

Fig. 5. *Oscillograms for a neon rectifier working against a back E.M.F.*

gradient in the discharge tube proportionately faster than the positive ions.

Hence the electrons tend to collect at the anode and become scarce at the cathode, whereas the distribution of the positive ions remains comparatively even. The resulting preponderance of positive ions constitutes a *powerful positive space charge*, and being situated in the immediate vicinity of the negative electrode, causes a high value of electric field ; the major portion of the whole potential drop between the electrodes occurs within this region.

The above conditions obtain when a steady (D.C.) P.D. is maintained between the electrodes. In the ordinary discharge

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tube, when an alternating P.D. is applied, the discharge conditions reverse completely for each half-cycle, at power frequencies—even the positive ions have sufficient mobility for this. At high frequencies there is not sufficient time each half-cycle for the space-charge to build up ; the conduction current becomes more a capacity current, ions moving only between adjacent regions of gas. The distribution of potential tends to remain uniform over the whole length of the discharge path.

VIII.—The " S-Tube " Rectifier.

Evidently a space-charge that reverses itself with reversal of the applied P.D. is of no use in producing asymmetrical conduction in the discharge. However, Bush and Smith* in their "S-tube" rectifier, have succeeded in making the space-charge " stay put " in one direction.

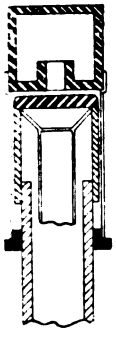

Fig. 6. *Section of " S-tube " rectifier.*

It will be seen from Fig. 6, which shows a diagrammatic section of the electrodes of this apparatus, that there is one large hollow electrode with a hole in one face, and opposite this hole and close to it a small flat electrode is placed. We shall see in a later section that the discharge *avoids* the short path between the edge of the small electrode and the edge of the hole in the other electrode, and takes place only along the long paths to the inside of the latter. Similarly, conduction between the outer faces of the electrodes is prevented by the proximity of the supporting tubes shown.

Let us consider first the application of a steady P.D. to this arrangement in such a direction that the hollow electrode is cathode and the small one anode. Then, as we have seen, a positive space-charge will build up in proximity to the active cathode surface, giving rise to the " cathode fall " of potential at this surface. The cloud of positive ions is found to occupy most of the volume inside the cathode, and therefore, the whole inside surface is subject to bombardment, and the electrons emitted from it are accelerated by the cathode fall and maintain the density of the positive ion cloud by ionisation.

* *Journ. Amer. I.E.E.*, 41, 627, Sept. 1922.

So far nothing abnormal has happened. But let us start *de novo* and make the hollow electrode anode instead of cathode. This time it is the face of the small electrode that is subjected to bombardment (if any) and from which electrons are released and accelerated by the cathode fall there. Such electrons produce ionisation *inside the hollow electrode*, which is where it occurred before ! Further, with a space-charge in the hollow electrode of the same sign as the charge on it (*i.e.*, positive) there is no potential gradient in the inner space. There is therefore no tendency for positive ions to move out of the cloud, except from the very small volume next the surface of the small electrode. In addition to the reduction of ionic bombardment due to this cause, the " short path " effect already referred to, which inhibits conduction, comes into action because of the close spacing of the electrodes.

Thus there are two favourable properties possessed by this arrangement. First, in whichever direction the P.D. is applied the tendency is to produce a preponderance of positive ions inside the hollow electrode ; it is obvious, therefore, that this condition will be equally as well established with an alternating P.D. as with a steady P.D. Secondly, this condition gives rise to an asymmetric conduction ; and here it must be recalled

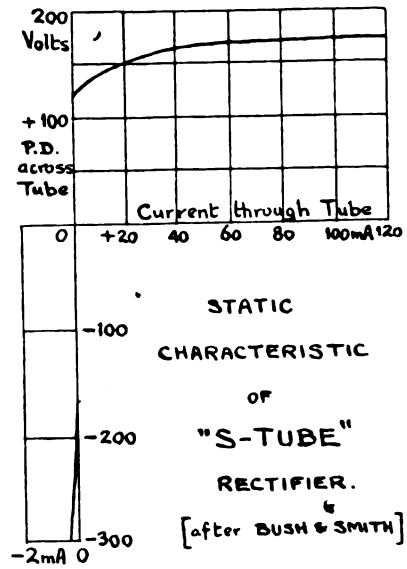

Fig. 7.

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that, in addition to the inequality of the active electrode areas, there are two further factors contributing to the smallness of the current flow with the small electrode negative as compared with the current in the reverse direction ; these are the small depth of the positive ion cloud available for supply of bombarding ions, and the "short-path" effect.

The "S-tube" therefore represents a big improvement on the type of glow discharge rectifier previously described. Its D.C. characteristic is shown in Fig. 7 ; it may be noted that the "inverse current" is of the order of 1/10 of that of the Neon tube, at moderate values of back E.M.F.

IX.—Practical Points in the "S-Tube."

It has been stated (see also Fig. 6) that by means of the small clearance between the supports of the electrodes, the discharge is prevented from creeping to any external region ; first, this ensures that the rectification effect shall not be short-circuited along external long discharge paths, although the containing bulb be made considerably larger than the electrodes to allow for the safe dissipation of the heat generated in them. Secondly, the only bodies that are in contact with the discharge are conductors ; this gives a steady and stable discharge ; it is

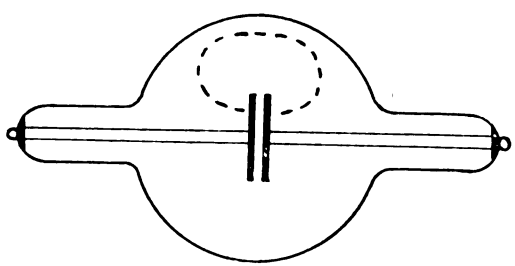

Fig. 8.
Discharge tube showing "long path" conduction.

known that the ordinary glass discharge tube is erratic in its behaviour, due to the accumulation and leakage of charges on the inner surface of the glass affecting the electric field distribution.

A further constructional feature is the use of specially prepared carbon for the electrodes ; this material is found to resist disintegration under the positive ion bombardment, and as a result the "clean-up" or disappearance of the working gas that accompanies the disintegration is largely eliminated. The tube therefore maintains a correct degree of vacuum over a reasonable working life.

X.—The "Short-Path" Principle.

This effect, which has already been mentioned in connection with the "S-tube," is nothing more than the condition that the longest path available in the discharge tube for an electron to pass from one electrode to the other is shorter than its "mean free

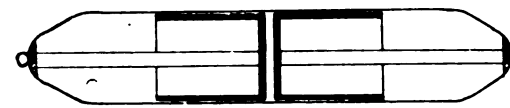

Fig. 9. *"Short path" tube, non-conducting.*

path." Under this condition, each electron, on an average, makes no collisions with any gas molecule during its complete passage ; there is therefore no ionisation and no glow discharge is possible. The only conduction that can take place is the minute amount discovered by Coulomb for ordinary air, called the "dark discharge."

The effect has been demonstrated experimentally. In a discharge tube, such as that shown in Fig. 8, conduction takes place along paths similar to the one shown dotted ; the glows appear on the backs and edges of the electrodes, but not on the opposed faces. On the other hand, by constructing a tube in the manner shown in Fig. 9, all lines of electrostatic force between the electrodes are made short compared with the mean free path of the electron, or else are interrupted by an isolated body capable of accumulating a charge. Such a tube will not pass as much as one microampere with a P.D. of 10 kilovolts applied to its electrodes.

XI.—Controlling the Length of the Electron Path.

One may describe the "S-tube" as an apparatus in which the length of path available for ionising electrons is controlled by *electrostatic means* (*i.e.*, by the positive ion cloud within the hollow electrode), in such a manner as to cause rectification. That electrons, being charged particles, should be susceptible to control by an electric field, has, in fact, been postulated as an essential characteristic of their behaviour in a gaseous discharge of electricity, whether under reduced pressure or not.

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It is possible, however, to control the electron *electromagnetically*, or rather, their *motion* may be controlled by such means. For an electron in motion is a moving charge of electricity, and so constitutes an *electric current* : in fact a current flowing in a conductor is nothing more than a flow of electrons along a specified path. Therefore an electric charge moving in a magnetic field experiences a transverse force just as an electric current does ; and its path becomes deflected in the same way as the conductor carrying the current would be, assuming it to be perfectly flexible.

Thus, if the discharge tube shown in Fig. 9 is immersed in a uniform magnetic field parallel to the planes of the electrode faces (and for convenience let it be perpendicular to the plane on which the figure is drawn) an electron moving from the face of one of the electrodes under the influence of the electric field between them is deflected laterally in a path like one of those shown in Fig. 10. The mathematics of the problem show that these paths are cycloids. The important point, however, to be noticed here is that, if the curvature of the path is sufficient, *i.e.*, the magnetic field strong enough, the electron will miss the further electrode and return to the one it originally left. This has the effect of *lengthening* the path, and if the gas pressure and the gap between the electrodes is suitably chosen, the path becomes greater than the mean free path, so that the electron stands a change of colliding with and ionising a gas molecule. Thus, by applying a magnetic field of sufficient strength, the tube of Fig. 9 may be made conducting.

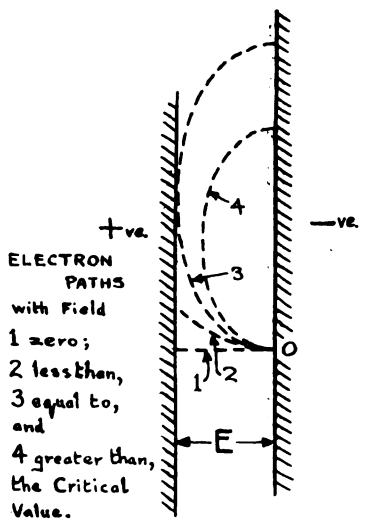

Fig. 10.
Showing cycloidal paths of electrons in magneton rectifier, produced by magnetic field parallel to electrodes. (The field is perpendicular to the plane of the figure.)

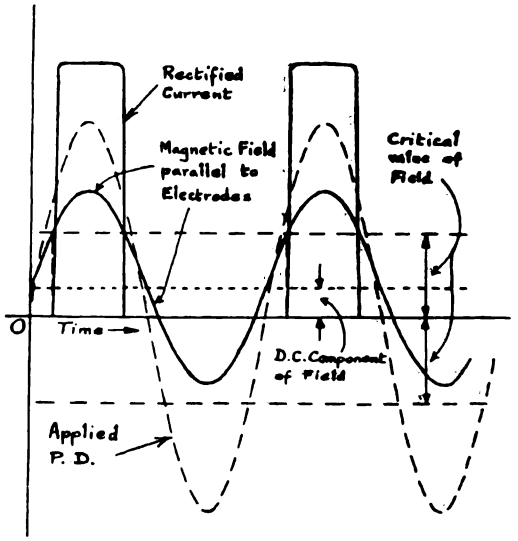

Fig. 11.
Oscillogram showing control of magneton by a variable field.

A second important point is to be noted—that as soon as the magnetic field exceeds the critical value, the electron path is immediately *doubled*. This is a valuable property of the arrangement, in that (theoretically) it allows a margin of 2 : 1 in the choice of the electrode gap or the gas pressure. It is found in practice that these should be such that the mean free path is three or four times the electrode gap.

By varying the magnetic field that is applied, the tube may be made to act as a switch, on the same principle as the Vibrating Flame Rectifier described in our last article.* The field used is provided by two windings, one carrying a continuous current, and the other an alternating current taken from the supply to be rectified. The currents are adjusted so that the field rises to the critical value for one peak of the supply P.D. but is too small when the reverse peak of the P.D. wave occurs ; thus a pulse of current will flow in one direction but the tube will remain insulating during the other half cycle. Note that the alternating component of the field (and hence the A.C. in the winding) must be kept closely in phase with the P.D. of the supply. The relationship described is depicted in Fig. 11.

(*To be continued.*)

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* E.W. & W.E., Vol. II., p. 897, Nov. 1925.

For the Esperantists. Distordado. [R800

Alia populara sofismo, rilate al senfadena ricevado, estas nun pritraktata: nome, ke kristalo kiel detektoro estas nebona. Ni ne povas tro emfazigi nian kontraŭstaron kontraŭ tiu kredo.

PARTO VA.

MALLONGIGOJ: A.F., Alta Frekvenco; M.F, Malalta Frekvenco; A.T., Alta Tensio; M.T., Malalta Tensio; K.K., Kontinua Kurento; A.K., Alterna Kurento.

LA A.F. AMPLIFIKATORO.

ANTAŬAJ artikoloj en tiu ĉi serio pritraktis distordadon kaŭze de l'amplifaj valvoj aŭ de l'intervalvaj kuploj. Ni devas nun pensi pri la restantaj eroj, el kiuj kompleto konsistas; la A.F. amplifikatoro, se tia ekzistas; la detektoro; la telefoniloj aŭ laŭtparolilo.

Ni unue pritraktos la A.F. parton, ĉar ĝi estas la plej simpla. La solaj fontoj de distordo tie-ĉi estas troaj selektiveco kaj oscilo. Ĉe ia A.F. amplifikatoro, krom multvalva, ambaŭ tiuj ĝenoj, se ili ekzistas, estos kaŭzitaj kredeble pro tro da reakcio. Reakcio, malpliigante la efektivan rezistecon de l'kompleto, povas ĝin tiel selektivigi, ke la altaj tonoj, kaj la altaj harmonikoj de la malaltaj tonoj, estos parte foragorditaj. Tiu-ĉi ĝeno estas tre malofta je mallongaj ondolongoj, kiel tiuj de la ordinaraj britaj kaj aliaj mallongondaj stacioj, sed ĝi povas esti tre evidenta ĉe la Daventry'a Stacio kaj aliaj longondaj stacioj.

La simptomoj estas plene evidentaj: malalta sonorega tono kiam la kompleto estas ĝuste agordita, ŝanĝiĝante al akra tono kiam iomete foragordita. Oni devas diri tute definitive, ke la ĉeesto de ĉi tia efekto estas tute nepardoninda, ĉar ĝi signifas, ke la aparato estas troŝarĝita, kaj estas preskaŭ kaŭzonta interferon al aliaj aparatoj.

FAKTOJ PRI LA DETEKTORO.

Nun, pri la detektoro. Ĉiu leganto kredeble aŭdis la diron—kaj tute ne kredis—ke kristala rektifo estas la plej bona por brodkastado. Ni tre deziras ripeti tiun diron kun tiom da emfazo, kiom nia sperto kaj rango rajtas; sed ni ĝin diros iom alimaniere:—

KRAD-REZISTANCA REKTIFO ESTAS LA PLEJ MALBONA METODO POR EVITI DISTORDON; KAJ LA PLIBONIĜO, POST ĜIA FORIGO, ESTAS REALA KAJ AŬDEBLA.

Aŭdebla, tio estas, se la M.F. amplifikatoro ne estas tiel malbona, ke ĝi difektos tion, kion la detektoro alportas.

La kialo por tiu-ĉi emfaza aserto estas simpla, kvankam detala teknika klarigo estus iom komplika. La krad-rezistanca detektoro, funkciante je modulitaj A.F. signaloj, rektifas tiujn de malalta aŭdfrekvenca modulo multe plibone ol tiujn de alta aŭd-frekvenco. La efekto estas pli malbona ĉe longaj ondoj, kiel ekzemple 5XX, ol ĉe mallongaj ondoj.

Se, pro aparta kaŭzo, oni *devas* uzi ĉi tian detektmetodon, oni povas ĝin plibonigi laŭjene: La krada rezistanco, kiel nune uzata, devas plenumi du celojn. Ĝi ebligas la solan konekton por K.K. inter krado kaj filamento, kaj tial malebligas al krado daŭre ŝarĝiĝi; kaj ĝi helpas, pro sia alta rezisteco, teni la kradon je unu K.K. tensio—iom malpli alta ol la tensio ĉe la punkto, al kiu la malsupro de la rezistanco estas konektita.

Konsideru Fig. 1. Jen la malsupro de la rezistanco estas konektita al punkto je + 4 voltoj. La malsupro estas ĉe iu

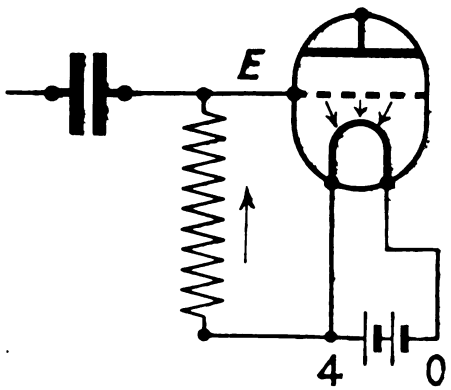

Fig. 1.

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voltkvanto E, nunmomente nekonata. Nu, ni scias pere de l'valva kurvo, kiom da krada kurento fluos je ioma ajn kvanto de E, kaj ni scias per la rezisteco de l'rezistanco kiom da kurento fluos tra ĝi pro iu

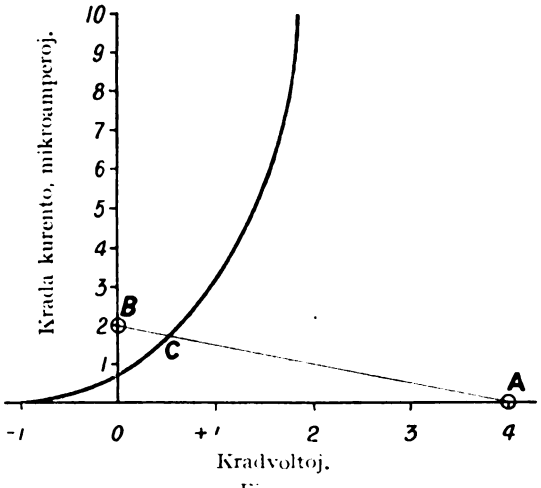

Fig. 2.

kvanto de (4 — E), kiu estas la tensio ĉe ĝi; do, oni devus povi trovi E, ĉar la kurento kiu trairas la rezistancon *devas* esti la sama kiel tiu, kiu pasas tra la valvo.

La figuro 2 bone ilustras tion. Tie la dika linio montras la kradan kurenton por iomajna voltkvanto ĉe la krado mem. Ni supozu, ke ni deziras uzi 2-megoman rezistancon. Marku la punkton A, kies voltkvanto egalas tiun punkton, al kiu estos konektita la malsupra fino de l'rezistanco —ekzemple la + de 4-volta baterio. Poste marku la punkton B, kiu reprezentos la kurenton, kiun la voltkvanto de A pasigos tra la rezistanco. Je la nuna ekzemplo, 4 voltoj dividitaj de 2 megomoj egalas 2 mikroamperojn. Kunligu A kaj B. La punkto C, ĉe kiu tiu-ĉi linio tranĉas la kurvon de la valva kradkurento, montras la voltkvanton, ĉe kiu la krado restos dum ne envenas signaloj. En nuna okazo, tio estas ĉirkaŭ ½ volto +.

Fig. 3 montras la efekton de rezistancoj diversgrandaj. Ili funkciigas la valvon ĉe diversaj punktoj de ĝia kurvo. Evidente unu punkto estas la plej bona. Sed povas esti, ke la grandeco de rezistanco, kiu produktas tiun punkton, *ne* estas la plej bona por ĝia alia funkcio—permesi la ŝarĝon elflui el la kondensatoro. Kiel oni povas solvi tion? Facile: ni uzu la ĝustan grandecon de rezistanco *kiel resistanco*, kaj variu la punkton, ĉe kiu la malsupro estas konektita. Tiel, Fig. 4 montras 1-megoman rezistancon konektitan al 1, 2, 3, kaj 4 voltoj. Efektive, kompreneble, la plej simpla rimedo estas uzi potenciometron transe de la filamenta baterio.

Kiam tio estas farita, provu rezistancojn ĝis eĉ 100 000-oma. Oni kredeble trovos, ke rezistanco ĉirkaŭ 250 000-oma produktos grandan plibonigon tonan; se oni provos ankoraŭ plimalgrandajn rezistancojn, povos esti malfortiĝo de signaloj.

KRISTALO KONTRAŬ VALVO.

Sed estas multe plibone eviti tiun metodon. Tion oni povas fari per du rimedoj. Unu estas uzi valvon kiel "anodan" rektifikatoron. Tio tamen kaŭzas perdon de signalforto, kaj, kiel ni montros poste, ne plene solvos la problemon. Al la kristala detektoro mankas ambaŭ tiuj difektoj. Ni baldaŭ montros, kiel oni povos forigi de ĝi distordon.

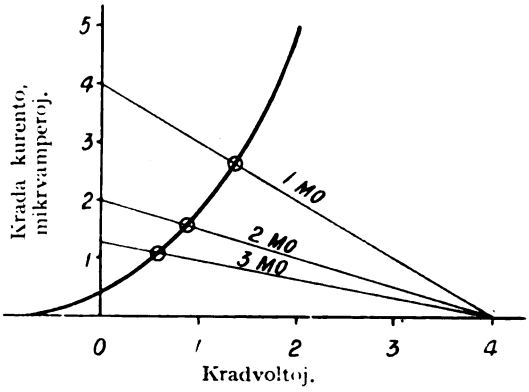

Fig. 3.

Sed, unuavide, ŝajnas absurde pretendi, ke neniom da perdo de signalforto okazos. Jen la argumento: la kosto kaj komplikeco de aparato kuŝas ĉe la valvoj. Tial ne estas juste kompari kristalon kaj 1-valvan aparaton kontraŭ 2-valva aparato. Ni devus kompari aparaton 2-valvan kontraŭ aparato 2-valva kaj kristala. Alivorte, ni devus konservi la valvon, kiu antaŭe funkciis kiel detektoro, sed ni devus utiligi ĝin kiel amplifikatoron kaj uzi kristalon por detekti. Oni trovos ĉiam, ke tio rezultiĝos je pliiĝo de forteco por la sama nombro da valvoj.

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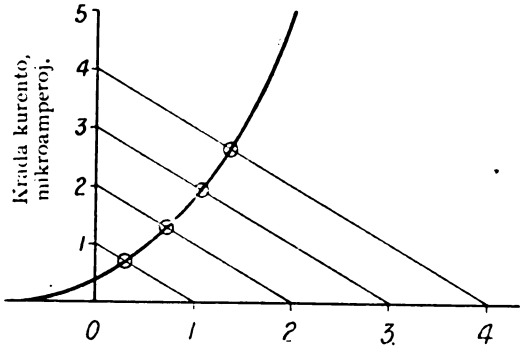
Ni nun pritraktu la kutiman kriegon de la valvamanto kontraŭ kristaloj — malstabileco. Tio estas absoluta sofismo *kiam oni ĝustmaniere uzas kristalon.*

La "ĝusta" maniero uzi kristalon *ne* estas meti ĝin transe de antena bobeno kaj provi ricevi malfortajn signalojn. Sub tia stato, oni bezonas ekstreman sentemecon, kiu signifas (A) tre malpezan kontakton—kun mekanika malfidindeco; (B) nur malmulte da egale bonaj lokoj; (C) iom da distordo; (D) selektivecon ne tiel bonan, kiel per valvo.



Kradvoltoj.
Fig. 4.

Kontraŭe, ni supozu, ke ni metos la kristalon post unu aŭ pli da A.F. valvoj uzantaj reakcion, kaj zorgos, ke estas forta enmeto ĉe la detektoro. Jen la rezulto: (A) firma kontakto estas uzebla; (B) preskaŭ iu ajn loko taŭgos por forta enmeto; (C) distordo tute for, aŭ almenaŭ nekonsiderinda; (D) reakcio kompensos kontraŭ la kristala ŝarĝo, kaj donos selektivecon egalan al tiu de valva detektoro.

GRAVECO DE BONA DETEKTORO.

Unu grava afero estas, uzi vere bonan kristalingon kaj kontaktilon, aŭ detektoran aranĝon, krom la kristalo mem.

Generale, la sinteza zinkita speco de kristalo ne estas tiel sentema kiel la galena; sed pro la grandaj enmetoj rekomenditaj, la diferenco ne estas granda. Estas tamen grave meti tian detektoron transe de iom pligranda bobeno kaj plimalgranda kondensatoro, ol taŭgus por galena detektoro.

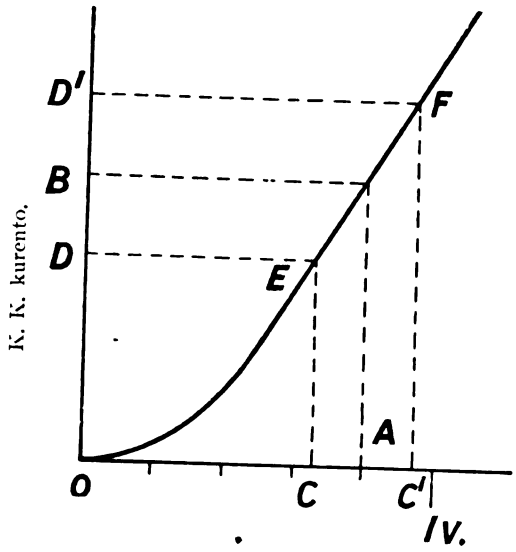
La moderna speco de daŭraj detektoroj estas bonega por ĉi tiu celo, kondiĉe, ke ili ja estas de la zinkita speco, kaj ne simple galenaĵoj.

KELKAJ NOTINDAĴOJ.

Jen noto, *kial* kristalo donas sendistordan rektifadon. Ni supozu, ke ni aplikos konatajn A.F. voltkvantojn al detektoro, kaj mezuros la K.K. elmeton. Ni obtenos kurvon, kiel tiun de Fig. 5. Nu, ni supozu, ke la portanta ondo naskas konstantan tension *A*. Ni ricevos konstantan kontinuan kurenton *B* ĉe la telefonilo. Kiam la modulo komenciĝos, la A.F. tensio varios je aŭda frekvenco de, ekzemble, *C* ĝis *C'*, kaj la elmeto varios de *D* ĝis *D'*.

Nu, *se, kaj nur se, la parto EF de la kurvo estas rekta linio,* la rektifita kurento estos ĝusta reprodukto de la sendila modulo. Praktike, la plimulto de bonaj galenoj *ja* montras tiun ĉi rektan linion, kondiĉe ke la tensio *A* estas ne malpli ol $\frac{1}{2}$ ĝis $\frac{3}{4}$ de volto; kaj zinkitaj detektoroj ĝin montras se *A* estas nemalpli ol 1 ĝis $1\frac{1}{2}$ voltoj. *A* devas ne esti *pli* ol, ekzemple, 3 aŭ 4 ĉe galeno, aŭ 6 ĝis 8 ĉe zinkito.

Tiurilate la kristalo estas la plej taŭga detektoro. Al valvo sen kradrezistanco mankas la ĝenoj klarigitaj jam en ĉi tiu artikolo, sed ĝenerale ĝi *ne* montras rektan parton ĉe sia rektifa kurvo.



A. F. voltoj.

Fig. 5.

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Letters of interest to experimenters are always welcome. In publishing such communications the Editors do not necessarily endorse any technical or general statements which they may contain.

The Tantalum Rectifier.

The Editor, E.W. & W.E.

SIR,—Our attention has been called to the article on page 889 of your issue for November. We notice that you describe a system of rectification which is employed in the Balkite Battery Charger, marketed by us in this country.

We would ask you to be good enough to state in your next issue that the basic patents employing the use of Tantalum as a rectifier are covered in this country under British patent No. 235658/1925, and that our associated Company, Radio Accessories, Ltd., of Hythe Road, Willesden, are the sole licensees for the manufacture of Tantalum Rectifiers in this country.

The patent stands in the name of the Fansteel Products Co. Inc., of North Chicago.

Various units incorporating this principle of rectification will be manufactured by Radio Accessories, Ltd. in due course and marketed by *this* Company. It is also our intention, in the near future, to sell to the amateur complete strips of Tantalum, so that he can, if he wishes, construct his own rectifier, in accordance with detailed instructions which will be issued, as soon as we have been able to make the necessary arrangements with the owners of the patent.

BURNDEPT WIRELESS LTD.,
Aldine House, Bedford Street, Strand, W.C.2.
W. W. Burnham, Managing Director.

The Editor, E.W. & W.E.

SIR,—As we know you get inquiries from time to time from your readers who wish to purchase special materials for Wireless work that are difficult to obtain, we should like to mention that if any of your readers are anxious to obtain supplies of Tantalum metal in sheet form (which is being much experimented with now for Rectifiers), and any other special metals such as Tungsten, Molybdenum, and rare metals generally, we can supply these specialities.

GEO. G. BLACKWELL SONS & CO., LTD.,
The Albany, Liverpool.
H. A. Blackwell, Chairman.

The "R.I." Transformer Curve.

The Editor, E.W. & W.E.

SIR,—I have read with interest the reply of Messrs. Radio Instruments to Mr. Anson's letter on the above subject.

As I understand it, the "R.I." theory is that small amplitudes are amplified less than large and that in consequence the deficiency in harmonics, the amplitudes of which are small, can be counteracted by the employment of a transformer which exaggerates the higher frequencies.

This theory is, in my submission, fundamentally unsound for the following reasons :—

(A) There is abundant theoretical and experimental evidence that the amplification factor of a transformer amplifier is not reduced to an insignificant value the smaller the input energy. On the contrary the variation is slight and the limiting amplification for very small amplitudes is definite and determined by the limiting permeability of the core at low alternating flux densities.

(B) If there were such a reduction in amplification a rising transformer characteristic would not improve matters, since the amplification of a fundamental note plus a harmonic would then produce a different effect from the sum of the effects of amplifying the fundamental note and the harmonic separately. Such a state of affairs would give rise to greater distortion of weak signals than of strong ones, and the fact that even very bad transformers do not exhibit this defect is the best practical evidence that Mr. Appleton's theory is wrong.

I enclose some measurements made on a single stage of transformer amplification at varying input amplitudes on two different frequencies, which support the contentions above outlined.

6, Bedford Square, W.C.1.
P. W. WILLANS.

[NOTE.—Unfortunately we have no space to reproduce the test curves. They show no change of amplification with strength between input voltages of .01 and .035 volts ; and the actual amplification is apparently the same as at quite large inputs.—ED. E.W. & W.E.]

The Editor, E.W. & W.E.

SIR,—I have read with interest the letter of your correspondent, Mr. Appleton, of Radio Instruments, Ltd. in the current issue of EXPERIMENTAL WIRELESS with reference to the required frequency response curve of an intervalve transformer. The ideas put forward are, to say the least of it, new to me.

In the first place, if the value of amplification differs considerably at different amplitudes, distortion of the "non-linear" variety will occur ; that is to say, if the wave form of the input E.M.F. is sinusoidal, then the output E.M.F. on the

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secondary of the transformer will depart from this shape by a greater or lesser extent, according to the difference in amplification for different amplitudes. It is well known that any wave form other than a sine wave can be analysed by a Fourier series into a wave form of a fundamental frequency plus a number of harmonics.

It will be seen, therefore, that if the amplification is not the same for all amplitudes certain undesired frequencies, which are harmonics of the input frequency, will be present. The intensity and number of these undesired frequencies will be a function of the non-linearity of amplification.

Further, if two sinusoidal E.M.Fs. of frequencies $f_1 - f_2$ be applied to the input of any non-linear amplifier, then owing to the fact that the amplification varies with amplitude, a certain amount of rectification will take place, resulting in the production of an E.M.F. of another frequency equal to the beat tone frequency of $f_1 - f_2$. The intensity of this beat tone frequency will again be a function of the non-linearity of the apparatus.

It would therefore appear that if the average transformer has the characteristics alleged by Mr. Appleton, then the amplification of music by such apparatus will result in a most serious distortion: that such distortion is not present can be proved in a very simple manner by performing the experiments indicated by the statements. What distortions are present in an amplifying chain are usually due to lack of grid bias on the valves, the overloading of valves, or a bad frequency response curve; that is to say, a curve indicating unequal amplification at various frequencies.

It is our considered opinion that all frequencies between 50 and 10 000 cycles are required for the perfect reproduction of speech and music; actually the frequencies between 100 and 1 000 cycles are very necessary for the warmth of musical tone and the naturalness and intimacy of the voice. The frequencies between 800 and about 2 500 cycles are required for intelligibility of speech and character and brilliance in music. The frequencies above 2 500 are required in order to produce the correct timbre of certain musical instruments and also to reproduce certain of the higher sibilants in speech.

Your correspondent further states that in order to amplify efficiently the frequencies of the order of 200 per second, it is necessary to increase the number of turns on the windings to such an extent that the amplification of high frequencies falls very considerably. That this is not necessarily the case is indicated by the fact that in the apparatus in use by the British Broadcasting Company there are several transformers whose performance is such that the frequency characteristic is essentially flat from 100 cycles up to 8 000. The falling off below 100 cycles and above 8 000 cycles is very small, however, and is not appreciable to the ear.

It may be of interest to note, however, that with certain types of loud-speakers which are bad reproducers of low tones, it is an advantage to use a transformer which removes the low tones completely. This, however, is not consistent with progress and development.

H. L. KIRKE.

The British Broadcasting Co., Ltd.,
2, Savoy Hill, London, W.C.2.

The Editor, E.W. & W.E.

SIR,—In your journal and elsewhere Messrs. R.I., Ltd., have published statements relating to low-frequency intervalve transformers that have given rise to much criticism and comment.

Many of these contentious statements have been received with incredulous amazement because they are advanced with the authority of experience.

One is, however, reminded of the remark of an indignant Silvertown mother concerning the young unmarried municipal nurse whose duty it was to visit the woman shortly after the birth of her seventh child. "The idea!" she fumed, "Fancy sending a person like that to teach me how to rear children. Me that 'as buried five!"

Mr. Appleton's letter in your November issue appears to furnish an explanation of the somewhat original views which gave rise to the protest to which he replied. In this letter we are told:—

(A) That musical sound is made up of a fundamental wave with a number of harmonics superimposed upon it, the latter having a very small energy-value in comparison with the fundamental.

(B) That transformers do not amplify these weak harmonics to the same degree as the fundamental.

(C) That it is consequently more desirable to discriminate against the low frequencies than to amplify all frequencies to the same extent.

(D) That the characteristic they publish "is a decidedly incomplete characteristic of the apparatus under test."

If your correspondent succeeds in establishing the truth of these contentions he removes the last shred of justification for publishing the curve as a symbol of merit, and for basing comparisons on any two such curves.

To the majority of your readers it will be obvious that the contentions are not in accord with current knowledge. The energy in individual overtones is often many times as great as that in the fundamental. I will give a few examples from the masterly analysis published by the Smithsonian Institution in *Physical Tables* (7th Edition).

Violin (*A string*): The fifth partial has 27 per cent. of the total sound energy while the fundamental has but 26 per cent.

Oboe: Only 2 per cent. of the total energy is in the fundamental, while 29 per cent. is in the fourth, 35 per cent. in the fifth, and 14 per cent. in the sixth partial, etc. Even the tenth has twice as much sound energy as the fundamental.

Clarinet: Of the twelve frequencies identified, the eighth, ninth and tenth have each more energy than the fundamental.

Trombone: More than one-third of the total sound-energy is in the third partial, while the fundamental has but one-seventeenth.

From these figures it is clear that any such discrimination as that suggested in (c) above, will exaggerate the peaks of the complex sound wave and produce harsh or squeaky sound such as we are in the habit of correcting by means of shunt condensers. If Mr. Appleton will turn to p. 745 of the September, 1924, issue of E.W. & W.E., he will find that the editorial report finishes up with the words, "We found a small condenser an improvement." Thus is Mr. Appleton's contention negatived both in theory and practice.

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I would remind your correspondent that the question at issue is, "Which of two published curves is the more correct?" and lest there be any doubt as to the interpretation of the term "correct" in this connection I refer again to the editorial view as expressed on p. 56 of Vol. 2 of this journal.

The tendency of modern practice leaves no doubt as to the obsolescence of transformers that fail to "pick up" below 2 000 periods per second. In the hands of a specialist they may have a limited application for purposes of discriminative correction, but they are now superseded as "general purpose" transformers by later designs based on the intensive experience of the past two years.

In conclusion I would suggest that a debate be arranged between Mr. Appleton and one of his critics, to take place before the Wireless Section of the Institution of Electrical Engineers or the Radio Society of Great Britain, the subject to be "Which of the two published curves is the more correct for a general-purpose intervalve transformer?"

WILLIAM D. OWEN.

Palmer's Green,
N.13.

The Editor, E.W. & W.E.

SIR,—I was very interested in Mr. Appleton's reply *re* the R.I. transformer curve, and was glad he called attention to the fact that "when the input energy applied to the transformer is below a certain value, the amplification factor practically disappears." However, I do not quite see how the harmonics suffer most in this respect. Harmonics are simply a part of a complex wave, and provided that the necessary energy is there, it appears to me that the harmonics would be fully amplified even though they were so weak that, had they existed separately, the amplification factor would have practically disappeared.

The question of impedance is another matter, and I agree that it is preferable to sacrifice something of the lower frequencies, if necessary, in order to preserve the overtones. None of the curves, in my opinion, are carried far enough. What kind of curves should we get if they were taken up to 10 000 cycles?

Just a word *re* your notes on amateur research. I find that there are so many problems in telephony reception, that I could spend my whole time experimenting instead of the few occasional hours which I can spare, and yet I know amateur experimenters who look on broadcast reception as beneath their dignity. Then there are others whose sole idea seems to be to get terrific volume from the loud-speaker with stunt circuits, and not appearing to mind that speech and music are quite unintelligible. May I congratulate you on the excellence of E.W. & W.E. and your avoidance of the stunt stuff. I feel that it is chiefly up to the amateurs to raise broadcast reception above the level of the demonstrations usually given in wireless shops, and it is here that the fundamental principles dealt with so thoroughly in E.W. & W.E. are so helpful. I have only one grumble, it is that we have to wait a month for the next issue.

H. H. DYER.

22, Leopold Street,
Derby.

Grid Rectification.

The Editor, E.W. & W.E.

SIR,—I have read with much interest Mr. F. M. Colebrook's paper on grid rectification in the November issue of E.W. & W.E.

From the tables of numerical values of his functions $G(x)$ and $\psi(x)$ on pages 870 and 874, I conclude that he has obtained these by summing the series given. I also think he has not taken enough terms of the series, for in every case his results are slightly out, especially for the higher values of x.

Mr. Colebrook has evidently not noticed that these functions are already well-known and accurately tabulated; they are in fact imaginary Bessel functions of orders Zero and Unity.

Thus, for his $G(x)$:—

$$G(x) = 1 + x^2 + \frac{x^4}{2!^2} + \frac{x^6}{3!^2} + \&c: = J_0(2jx)$$

Values to four places are given in Jahnke & Emde's *Funktionentafeln* (Teubner, Leipzig), page 130 of the 1923 edition, from $x=0$ to $x=11$, by intervals of 0.1 from 0 to 6, and of 1 from 6 to 11.

From these tables I take the figures in column 4 of the attached schedule, column 2, giving Mr. Colebrook's values of $G(x)$.

$x =$	$G(x)$ (*Colebrook*)	$2x$	$J_0(j.2x)$ (*J. & E.*)	$-jJ_1(j2x)$
0	1	0	1	0
.25	1.0634	.5	1.0635	0.2579
.50	1.2660	1.0	1.2661	0.5652
.75	1.6466	1.5	1.6467	0.9817
1.00	2.2795	2.0	2.2796	1.5906
1.25	3.2882	2.5	3.2808	2.5167
1.50	4.8790	3.0	4.8808	3.9534
1.75	7.3690	3.5	7.3782	6.2058
2.00	11.2990	4.0	11.3019	9.7595
2.25	17.4800	4.5	17.4812	15.3892
2.50	27.2700	5.0	27.2399	24.3356
2.75	42.7600	5.5	42.6946	38.5882
3.00	67.5000	6.0	67.2344	61.3419

In the same way, Mr. Colebrook's function $\phi(x)$ is:—

$$\phi(x) = x + \frac{x^3}{1!2!} + \frac{x^5}{2!3!} + \frac{x^7}{3!4!} + \&c: = -j.J_1(2jx)$$

The values of this from Jahnke & Emde (pp. 131 to 133) are in the fifth column of the attached schedule.

Thus, finally, for Mr. Colebrook's $\psi(x)$:—

$$\psi(x) = \frac{x.G(x)}{\phi(x)} = \frac{x.J_0(2jx)}{-j.J_1(2jx)} = j.\frac{x.J_0(2jx)}{J_1(2jx)}$$

Numerical values of these functions may also be found, for larger intervals of the argument, in Dale's *Five Figure Tables of Mathematical Functions* (Arnold, London), where they are tabulated with a slightly different notation,

$$G(x) = I_0(2x)$$
$$\phi(x) = I_1(2x)$$

whence, in Dale's notation:—

$$\psi(x) = \frac{x.I_0(2x)}{I_1(2x)}$$

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Dale's tables also give values of I_2, I_3, etc. : up to I_{11}, which are not found in Jahnke & Emde ; but at intervals of 0.2 in the argument only, from 0 to 5.

I would suggest that Jahnke & Emde's "Funktionentafeln" are most useful to anyone engaged upon the mathematical side of wireless. They can be found in any good library, or bought through a bookseller who deals in foreign books (for about 7s. 6d.). These "tafeln" not only give numerical values of an immense variety of the less common functions, but also graphs of these functions and invaluable lists of integrals which can be found in terms of the functions, and of differential equations to which the functions are solutions.

Hoping that this suggestion may save Mr. Colebrook a vast deal of arithmetical work in the summing of series.

C. R. COSENS.

13, Millington Road, Cambridge.

The Editor, E.W. & W.E.

SIR,—I am much indebted to your correspondent, Mr. Cosens, for his information with regard to the series in my paper on valve rectification. At the time of writing the paper I anticipated that the series were actually known and tabulated functions, but failed to recognise them. I certainly wish I had done so, as the series are by no means rapid in their convergence. As it is, I must be thankful that my arithmetic has not let me down, for the values I have given are in agreement with the tabulated values to a greater degree of accuracy than experiment on the subject is likely to require.

F. M. COLEBROOK.

The National Physical Laboratory,
Teddington.

H.T. Supply from the Mains.

The Editor, E.W. & W.E.

SIR,—One notices from time to time various articles describing how current can be obtained from the lighting mains to supply wireless sets.

A perusal of some of these articles indicates that the authors are not familiar with the regulations governing electricity supply.

I notice in one paper a paragraph which reads as follows :—

"Incidentally the potential of the 'earth' side of the switch to earth *can* be used as an absolutely gratis source of current, but it is subject to remarkable fluctuations which make it unreliable for charging accumulators."

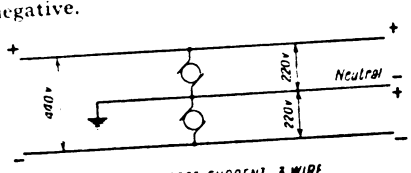
The text matter preceding it does somewhat modify it, but I can imagine a schoolboy getting hold of this particular paragraph and causing the supply authorities a good deal of trouble in trying to trace earths.

I think it would be of general benefit if you would point out that the Electricity Regulations specifically lay down that the neutral of a distribution system must only be earthed at one point. This point is usually at the generating station, or, in the case of an isolated network, at the sub-station.

This does not prevent a wireless set being earthed by the means of condensers, but it does prohibit *any other kind of earth* such as one side of the high tension supply.

The attached two little diagrams may make the method of supply clear to amateurs.

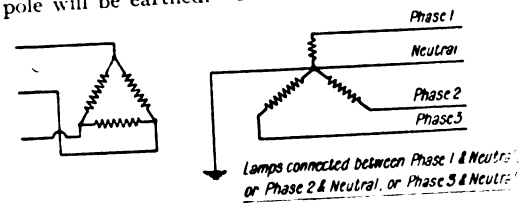
In the first case we have a very common form of distribution, namely, 3-wire direct current with, say, 220 volts between each conductor and the neutral, and 440 volts across the neutral. In this case the lighting load is connected to the main so that half would be on the positive side and half on the negative.



DIRECT CURRENT, 3 WIRE

This is a point which should be remembered when using the main for high tension supply, as it will be obvious from our diagram that approximately 50 per cent. of the houses will be connected in such a manner that the positive is earthed.

Large motors are usually connected across the outers, *i.e.*, across the 440 volts so that neither pole will be earthed. This form of distribution is



ALTERNATING CURRENT 3 PHASE 4 WIRE DISTRIBUTION

being largely superseded by 3-phase alternating current. The distribution connections for this system are also shown in the sketch, the neutral being earthed at the transformer.

JAMES NELSON.

7, High Street,
Prescot, Lancs.

"Wipe Out."

The Editor, E.W. & W.E.

SIR,—I should like, if space permits in your columns, to reply to the letters of Dr. R. L. Smith-Rose and Mr. Marcus G. Scroggie which appeared in the November issue of E.W. & W.E.

(1) I, personally, am entirely in agreement with Dr. Smith-Rose that the term "Wipe Out" is undesirable when applied to "Automatic Synchronisation," and should only be applied to the case he quotes.

Owing, however, to certain correspondence I had on the subject some time ago, I was under the impression that the term "Wipe Out" was not uncommonly used amongst amateurs to include "Automatic Synchronisation." It was in order to try and clear up a fallacy which seemed to be held by many, and classed, it appeared, under the general heading of "Wipe Out," that I originally wrote the article which appeared under the heading of "Wipe Out" in the October issue of E.W. & W.E.

(2) With regard to the phenomenon which puzzles Mr. Scroggie, I am rather inclined to think that he has only struck one of the ordinary features characteristic of "Automatic Synchronisation."

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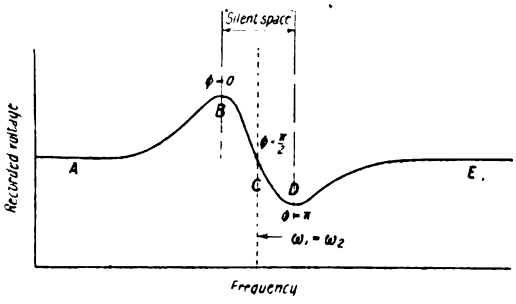
The question of the phase difference between the voltages of two coupled oscillating circuits during the period of synchronisation is dealt with very fully in Dr. Appleton's paper referred to in my original article. The theory is too lengthly to recapitulate here but the conclusions may be mentioned.

Suppose two oscillations are coupled together in such a manner that automatic synchronisation can take place, and suppose a third circuit is coupled



to them in such a way that the combined voltages produced by the two oscillators are recorded in this circuit on some indicating device, *e.g.*, Moullin voltmeter, crystal and galvo, etc., then these conditions will correspond to those described by Mr. Scroggie—his circuits being a particular case of the general form described above.

Now let observations be taken in the recording circuit when the frequency of one of the oscillators is approached to that of the other. If the voltage indeed in the recording circuit is plotted against change of frequency, a curve of the type shown in the figure will be produced.

As the frequency of one oscillator (ω_1) approaches that of the other (ω_2) the recorded voltage rises till a maximum is attained as the commencement of the silent space is reached (point *A*), *i.e.*, when automatic synchronisation takes place. As the silent space is traversed the voltage drops very rapidly and reaches a minimum as the beats start again (point *D*) and thence rises to its normal value at *E*.

This voltage variation represents a changing phase difference (ϕ) between the two sets of oscillations. The phase relations go from $\phi=o$ through $\phi=\pi/2$ to $\phi=\pi$. This rapid phase change during the silent space may be accounted for theoretically if the oscillators are assumed to have characteristics of the form

$$i=f(v)=-\alpha v+\beta v^2+\gamma v^3.$$

and this approximates to a triode characteristic. These phase changes may be observed by the Lissajon's figures produced in a suitably arranged cathode ray oscillograph.

This may explain the phenomenon Mr. Scroggie observed, only it would appear that he approached the silent space from one side and not the other, since he makes no mention of a *fall* of recorded voltage on approaching the silent space in one direction, as would happen from *E* to *D* in the figure.

If this explanation is to hold good for Mr. Scroggie's experiment, (1) the minimum recorded voltage would occur at one side of the silent space and *not* throughout, the voltage variations taking the form shown in the figure; and (2) for two oscillations of unequal voltage the drop would only be equal to "double the difference between the two" for one particular case.

However, the similarity between the phenomenon I have described and that of Mr. Scroggie is sufficiently near to warrant my putting forward the above explanation, and it might well transpire that a check of Mr. Scroggie's observations might show substantial agreement with what I have described, or else Mr. Scroggie may find an explanation for his own case in the light of what I have stated.

In any case, I should be interested to hear if Mr. Scroggie has been in any way helped by what I have had to say.

Barracks, DESMOND DE BURGH.
Mayfield, Sussex.

The Editor, E.W. & W.E.

SIR,—Referring to the phenomenon noticed by Mr. Scroggie and published in the November issue.

It is well known that the inductance of a coil is decreased when the flux of coil *A* threads coil *B*, and produces a current, this current producing a second flux which increases the reluctance of coil *A* and so decreases the inductance. If, however, the current in coil *B* is made to lead the voltage by 90 deg., the flux of coil *B* will decrease the reluctance of coil A and so increase the inductance.

An effect analogous to the above may be happening in the phenomenon referred to, that is to say, the oscillator may actually radiate waves 180 deg. out of phase with 2LO, notwithstanding the fact that 2LO is acting as a "drive oscillator."

A close study of the oscillator circuit used by Mr. Scroggie may confirm the above theory.

SAMUEL H. BROWNING, A.Rad.A.
43, Clarinda Park E., Kingstown, Co. Dublin.

Proposed Institute of Radio Engineers.

The Editor, E.W. & W.E.

SIR,—With reference to your editorial comment on my letter published in your November issue, I fear that, in turn, you may have misunderstood the object of my letter, which was not written with a view to entering into any controversy as to whether or no the Institution of Electrical Engineers properly serves the wireless engineer, but to correct certain statements made by Mr. Gambrell, which I believe to be misleading, regarding the status and training of a wireless engineer.

34, Norfolk Street, B. BINYON.
Strand, W.C.2.

Reversing Coils.

The Editor, E.W. & W.E.

SIR,—In your article on O'Keeffe Plug-in Coils in the November issue, it is stated that a good feature of these coils is their reversibility.

It should be remembered, however, that the reversal of the coil will entail the reversal of the coil connections; therefore, the direction of the lines of force will remain unchanged.

Wishing your magazine every success.

40, Wingford Road, A. W. SUMBLER.
Brixton, S.W.2.

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The Australian DX Record.

The Editor, E.W. & W.E.

SIR,—A letter appears in your issue of last July under the heading of "The Australian DX Record" and signed by J. H. D. Ridley.

While congratulating Mr. Ridley on getting his short-wave signals across to Australia, he has made a mistake as to the date of the reception by me of Mr. Simmonds' transmission. This was on Sunday, 26th April, and not the 27th as stated in Mr. Ridley's letter. I cannot give the exact time of the reception as it occurred during a test period. However, it is certain that it was before 4.45 p.m., for I have a later entry in my log, time 4.45 p.m., covering two-way working with U6TS and U1CMX, on 20 metres.

Faint 20 metre signals had been heard calling me on 19th April, but although my call-sign (2CM) was distinguished there is a doubt as to the station calling. The only guide to this is, that it contained the figure 2 and the letter K. I therefore considered it to be 2KF who I knew would be calling me at this period.

The date of the first reception of the signals from my station, in England, by Mr. Partridge and Mr. Morrow was 15th April, and the date of the first two-way working between Mr. Simmonds and myself was 2nd May.

CHAS. MACLURCAN (A2CM).

4th Floor, Pratten Buildings,
26, Jamieson St., Sydney.

Station News.

The Editor, E.W. & W.E.

SIR,—May I take this opportunity of advising you that each Thursday at 10.30 p.m., and each Sunday at 11 a.m., I shall be transmitting on a wave-length of 9.2 metres for a period of half an hour, with intervals of five minutes between transmissions of a similar duration.

If you will make this announcement in your paper I can guarantee positively that these transmissions are being carried out to schedule.

Reports are welcomed.

33, Castlegate, N. G. BAGULEY (G2NB).
Newark.

The Editor E.W. & W.E.

SIR,—Will you kindly note that I shall be transmitting on wave-lengths of 103 metres and 440 metres in the course of a week or so. QSL cards welcomed, and will be answered.

"Fiveways," G. S. WHITE (G2GW).
Chippenham, Wilts.

The Editor, E.W. & W.E.

SIR —Kindly note that the QRA of this station is now: G6UG 10 watts 150/200 metres. QSL cards answered per return.

18, Albion Street, H. DEAN POULTON.
Cheltenham.

The Editor, E.W. & W.E.

SIR —I should be glad to get into touch with another amateur desirous of working phone on 150/200 metres, within a radius of 50 miles.

My station call is 6MW.

Clifton House, C. W. THOMAS.
Old Swinford, Nr. Stourbridge.

The Editor, E.W. & W.E.

SIR,—Would you be so kind as to publish the fact that I have been allotted the call 5KU in place of 2APW. This is for CW and phone on 45 and 23 metres.

Wishing E.W. & W.E. all the best.

4, Glenhurst Avenue, R. POLLOCK.
N.W.5.

The Editor, E.W. & W.E.

SIR,—Please note the address of my station, 2JP, is now "Brooklands," Follifoot, Harrogate. Transmissions are carried out on wave-lengths of 95 and 45 metres, and all reports will be welcomed.

17, Princes Street, M. C. ELISON.
Harrogate.

The Editor, E.W. & W.E.

SIR,—I should be very glad if you would be kind enough to publish my call-sign, etc., as below at your early convenience.

5KR, wave-lengths 150-200 and 440 metres, watts 10.

The Crossways, C. M. THORPE.
Rhuddlan, N. Wales.

The Editor, E.W. & W.E.

SIR,—It may be of interest to you to note that the P.M.G. has granted me an artificial aerial transmitting licence, the call-signs allotted to me being 2BCT.

I have also been granted permission for use of a transmitter using a frame aerial for remote control of a model boat.

Congratulations on the continued excellence of E.W. & W.E., and best 73's.

23, Palmer's Avenue, A. G. WILLIAMS.
Grays, Essex.

The Editor, E.W. & W.E.

SIR,—I should be glad if you would make known the fact, through the next issue of your excellent journal E.W. & W.E., that my station 5XW is now active on wave-lengths between 150 and 200 metres, and that reports on the transmissions are welcome and will be answered. Usual QRH 168 metres.

Wishing you every success.

5, Cretfield Road, C. BRYANT.
Colchester.

The Editor, E.W. & W.E.

SIR,—The P.M.G. has allocated to me the call sign 6YU, and I should greatly welcome reports on my transmissions, which at present are on 45 metres.

All QSL cards acknowledged.

Thanking you for the pleasure and help I derive from your excellent journal.

56, Falstaff Gardens, J. HANSON.
Radford, Coventry.

A Correction.

With reference to the Radio Relative Index published in E.W. & W.E. for November, the classification for intervalve input and output couplings for amplifications should be R132.1-3 and not as given.

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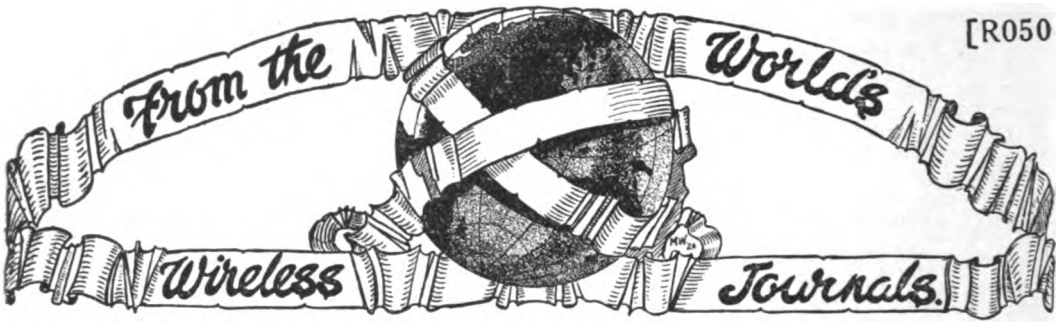

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R100.—GENERAL PRINCIPLES AND THEORY.

R113.—Report on Measurements made on Signal Strength at Great Distances during 1922 and 1923 by an Expedition sent to Australia.—H. J. Round, T. L. Eckersley, K. Tremellen and F. C. Lunnon of Marconi's W.T Co., Ltd. (*Journ. Inst., E.E.*, Oct., 1925).

This is a very lengthy paper read before the Wireless Section of the I.E.E. on 6th May. A short preface by Capt. Round recapitulates early signal strength measurements, and outlines the expeditions whose results are detailed. The method and apparatus used are then described. A measured local signal was introduced into either the working aerial or a dummy aerial to equal that in the receiver, the well-known "slide back" method being used for measurement. The apparatus was all carefully screened and an accuracy of 10 per cent. is claimed in the measurement of received signals under all the same exceptional conditions of atmospherics. In 1921, the apparatus was used for the measurement of American signals at Chelmsford, and also at other parts of Great Britain. Curves are given for signal E.M.F. against time (in hours). The mean daylight value measured was, for Chelmsford, of the order of 2.1 or 2.2 and that for Girvan, Ayrshire, 3.3 or 3.4 times that due to be received by calculation from the Austin Cohen formula. An interesting figure shows results at Chelmsford for four American stations reduced for comparison to the value of a 140 000 metre-ampere station. A sudden and very marked decrease is shown in the early weeks of November, the lower though increasing value holding through the winter months. A series of measurements were also made in South Africa in August-September, 1922, curves being shown for the reception of UFT and WQK. It is pointed out that the signals from European stations are approximately halved by their overland route as compared with those more wholly oversea from America.

The next sections then describe measurements made during an extensive world cruise. In January, 1922, observers left England in S.S. *Dorset*, proceeding by the Atlantic, Panama and Pacific to New Zealand. The gear was there unshipped and transported to Australia, where measurements were continued. The return journey was made in S.S. *Boonah*, *via* the Indian Ocean and Mediterranean. Curves of signal strength from various European and American stations are given for the complete journey. Measurements aboard ship are shown in the form Field Strength ($\mu V/m$) against distance from transmitter, and those for land observations in Australia in the form microvolts at 60 feet actual height against time, in hours. The text discusses the measurements and curves. A notable point is that when in the Pacific Ocean, it was detected that signals from New York stations were being simultaneously received round the world in both directions. Here and elsewhere it appeared that signals frequently preferred a longer dark route to a shorter lit path. A considerable section is devoted to atmospherics. Directional reception indicates origins of considerable distance, especially of the X's received on the longer waves. Apart from purely local thunderstorms various large areas of land in or near the tropics are shown to be productive sources, varying with season, and having a maximum about 3 p.m. local time. Between midnight and 02.00 G.M.T. S. America contributes a steady supply. Information as to the microvolts per metre necessary to read through X's is stated to have been obtained, but is not published.

The latter half of the paper gives a theoretical discussion of the results. The Austin Cohen formula is abandoned as giving inadequate information regarding the nature of transmission. A form due to G. N. Watson is suggested as suitable. This formula includes an attenuation factor depending upon the resistivity and permeability both of the earth and of the upper layer, and upon the height of the layer. This is finally simplified by the authors to a working form

$$E = \frac{120\pi h I_t e^{-ad/\sqrt{\lambda}}}{\lambda(d_0 R \sin\theta)}$$

Where h = effective height of transmitter (in km.)
λ = wave-length in km.
I = transmitting current.
θ = zenith angle between transmitter and receiver.
d = distance.
a being the attenuation factor and d_0 being approximately at $3H/2$, where H is the height of the layer.

Values of attenuation are tabulated for the *Dorset* voyage, the figures for the Atlantic voyage being shown separately for European and American stations, on account of the difference of their routes. The values are .001 8 and .001 42 respectively. For the Pacific portion of the cruise the value measured on European stations is given as

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.000 955. For the *Boonah* return voyage the values shown in tables are .001 07 for the European and .001 24 for the American stations.

Land absorption is discussed on a basis of (*a*) Dielectric losses in surface vegetation; (*b*) Conduction losses in various structures on the surface as well as surface vegetation. The night effect in long distance transmission—including the bi-directional transmission already referred to—is then considered, and the theory and effect of the upper layer is dealt with. It is concluded that day transmission is confined to the space between the earth and the lower conducting layer, and at night when the ionising effect of the sun is absent, the lower layer disappears, and the upper auroral layer comes into play with its much better defined reflecting surface. It can thus reflect radio waves at much greater angles than those of day time. As a consequence there is the irregular interference phenomena so characteristic of night transmissions which must be due to slight variations in the height and conductivity of the layer. Evidence from other sources is quoted in support.

Lastly, reference is made to the fact that on the data there appears to be a superiority of transmission from West to East as compared with that from East to West. It is suggested that this might be explicable by effects of electronic or ionic movement in the earth's magnetic field, but no very definite conclusion is reached.

R113.4.—WAVE PROPAGATION AT HIGH FREQUENCIES.—Dr. A. Hoyt Taylor and Dr. E. O. Hulbert (*Q.S.T.*, Oct., 1925).

After briefly considering the process of ionisation in the upper air, the authors proceed to discuss the effect of the ionised layer at the higher radio frequencies, *i.e.*, wave-lengths of 10 to 40 metres. Reference is made to the fact that short wave signals are usually received better at a distance than near to the transmitter, while there is a "skipped distance" in between where they cannot be received. Typical "skipped distances" for various short wave-lengths are shown by a curve. This is explained by the rapid absorption of the direct and earth-bound ray, and the reflection from the ionised layer of the indirect ray to much greater distances. The authors estimate an electron density of 5.57×10^5 electrons per cubic centimetre as the value necessary to turn back these short waves, and show typical ray paths for the reflected wave according to different assumptions of the variation of electron density with height.

R113.8.—THE EFFECT OF THE SOLAR ECLIPSE OF 24TH JANUARY, 1925, ON RADIO RECEPTION. —G. W. Pickard (*Proc., I.R.E.*, Oct., 1925).

This paper, which is a communication from U.R.S.I., gives graphical results of many measurements of field strength taken in different parts of U.S.A. during the eclipse last January. The eclipse occurred shortly after 9 a.m. (American time) and many of the graphs give interesting comparisons of the eclipse effect alongside the night effect of the preceding hours on wave-lengths of 300 to 500 metres. The results are well presented by a mean graph in which the eclipse effect is superimposed on (*a*) the normal morning fall of mean field, and (*b*) the normal morning fall of the fluctuations about mean field value. The effect of the relative positions of transmitter and receiver with respect to the shadow band is considered from reference both to these and to other eclipse observations. A "Bibliography of Eclipse Effects" is appended, with a later communication by the author giving results of measurements made in New York City on the 75 metre signals from Schenectady.

R113.9.—SOME MEASUREMENTS ON WIRELESS WAVE FRONTS.—R. L. Smith-Rose and R. H. Barfield (E.W. & W.E., Sept., 1925).

After a review of preliminary theory of wireless transmission, the authors describe the use of a straight-wire rotating aerial (Hertzian rod), and a rotating loop for the determination of the electric and magnetic components respectively of an arriving wave. Results are given of the use of this apparatus at short distances from the transmitting stations. These show practically negligible tilt of the electric component in the plane of propagation on medium waves of 2 000—7 000m. at distances up to 36 miles, and a maximum tilt of 2.7 degrees on 450m. at 12 miles. The results are used to determine the earth's conductivity at the receiving station, and further experiments with portable apparatus are described, giving similar determinations at various places. A mean resistivity of 5 000 ohms per cubic centimetre is quoted. Wave-front measurements at greater distance from the transmitting stations are then described. It is stated that waves arriving from appreciable distances (*e.g.*, up to 600 miles), and under conditions such as might give rise to d.f. errors, are not readily distinguishable (by measurement of the electric and magnetic fields) from those propagated horizontally from nearer stations. The necessity for continued work on shorter wave-lengths is indicated in conclusion. The work described has been carried out under the direction of the Radio Research Board.

R125.1—THE POLAR CURVES OF RECEPTION FOR SPACED AERIAL SYSTEMS.—E. Green (E.W. & W.E., Oct., 1925).

The author first considers the simplest of polar curves, *i.e.*, the circle of a nondirectional vertical aerial, the figure of eight diagram of a d.f. frame, and their combination into a cardioid or heart-shaped polar diagram, with additional reference to a cardioid with a small single pip due to inadequate vertical component. He then considers the use of two vertical aerials, spaced a fraction of a wave-length apart, and mutually led to coupling circuits in the station midway between. The use of these aerials to produce a figure of eight diagram is described and well illustrated by vectors of the phase relations. The change of phase relations by the detune of low decrement closed circuits in the station is described and illustrated by vectors to give a cardioid, as is the production of a pipped cardioid by incorrect phasing. The effect of aerial spacing is considered, one-fifth to one-sixth of a wave-length being stated to give maximum signal strength. It is also stated that the spaced aerial gives great freedom from atmospherics. The use of pairs of d.f. frames at each point, instead of the vertical aerial, is then considered, with the combination of their polar diagrams and mistune to give

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a cardioid. Polar diagrams obtained under various conditions are very fully illustrated. The article concludes by well-summarised instructions for the compounding of the factors involved in the construction of a polar curve.

R133.—THE VALVE AS OSCILLATION GENERATOR.—Dallas G. Bower (*Electrician*, 9th Oct., 1925).

A description is given of the use of the valve to generate continuous oscillations. Curves show the phase relations between the grid potential and the anode current and potential. Expressions are given for the efficiency of the device, and the effect of working at a bent portion of the characteristic curve is discussed.

R134.—DETECTING CHARACTERISTICS OF ELECTRON TUBES.—H. M. Freeman (*Proc. I.R.E.*, Oct., 1925).

After pointing out the advantages of the valve as a detector, the author refers to the increasing need for "special purpose" valves. He then considers the operation of a detector working with cumulative grid, giving curves of detector output derived from considerations of the static characteristics. The paper then describes work done at the Westinghouse Laboratory, East Pittsburgh, in experimental confirmation of these valves. The rectified outputs from several different valves were measured, using a "slide-back" arrangement. The work was performed in a cage shield to screen the apparatus from various local sources of disturbance (including KDKA). Experimental curves were obtained in good agreement with those calculated from static characteristics, and it is shown that the method can be used to measure the effect of variations in operating conditions on the detector efficiency. Curves are given showing the effect of such variation, as well as the variations in the detector efficiency of several similar valves worked under their normal operating conditions, explaining why considerable improvement can often be made by (as the author puts it) "juggling the tubes around."

R135.—DISTORTION IN WIRELESS TELEPHONY, AND RELATED APPLICATIONS OF THE CATHODE RAY OSCILLOGRAPH.—E. K. Sandeman and N. Kipping (E.W. & W.E., Sept. and Oct., 1925).

The September article gives a general discussion of the causes producing distortion in wireless telephony. The various types of distortion are defined, and the chief causes producing each type are stated and discussed.

The October article discussed the application of the Cathode Ray Tube to various determinations of wave form, and other purposes. Sections, with appropriate illustrations, are given on (*a*) Wave form of atmospherics; (*b*) dynamic valve characteristics (with photographic illustrations); (*c*) percentage modulation (with photographs); (*d*) asymmetric distortion (with photographs); (*e*) frequency resonance curves; (*f*) other related applications, including frequency determinations by the ordinary method of Lissajon's figures and by the method of using the source under examination to vary the accelerating voltage and deflectional sensitivity.

Appendix I. (Sept.) gives a mathematical explanation of the processes of modulation and detection. Appendix II. (Oct.) describes the use of neon lamp circuits for the production of a linear time base voltage for use with the Cathode Ray Oscillograph. A bibliography is also appended.

R138.—LIFE TESTING OF TUNGSTEN FILAMENT TRIODES.—W. C. White (*Proc. I.R.E.*, Oct., 1925).

The author points out that life testing is a subject on which little has been published, and gives reasons for the importance of the subject. The chief of these are:—

(1) To verify that no details have been overlooked conducive to a satisfactory operating life.

(2) To permit the best choice of proposed details of design.

(3) To detect marked changes in the life quality of valves regularly produced.

(4) To aid in the choice of the best raw materials.

(5) To determine the most satisfactory exhaust method.

(6) Verification of characteristics during operating life.

(7) To learn the effect on life of different combinations of operating conditions.

Extensive life tests made at the Schenectady Laboratory of the G.E.C. are then described, with information and illustrations of the apparatus and methods employed. Various tables are given showing the life-test results of different batches, with a statement of the type of valve in the batch, operating conditions, hours of life and cause of failure. In one case of a Radiotron UV 201A a life of over 11 500 hours is recorded when the valve was removed from test although it had not then failed. In the same batch two others gave 10 500 and 10 000 hours respectively, while a batch of the same model, but defective, yielded lives of 75 to 125 hours. Statistical results of many of the tests are illustrated by curves. Curves are also given showing the effect of variation of filament voltage upon the life (of a tungsten filament). The author concludes by emphasising that the life of a valve is not a constant for any particular type, but is as variable as are most of the other characteristics.

R138.—THE APPLICATION OF X-L FILAMENT TO POWER TUBES.—J. C. Warner and O. W. Pike (*Proc. I.R.E.*, Oct., 1925).

This article, written from the G.E.C. Research Laboratory at Schenectady, N.Y., describes work done on the application of the thoriated tungsten (X-L) filament to power valves. The authors discuss the general properties of the thoriated tungsten filament and its advantages over other materials (particularly over the pure tungsten filament) for use with power valves. A table gives an interesting comparison of the X-L and pure tungsten filaments used in various radiotrons named, the characteristics quoted varying between an emission of 4.5mA per watt for a tungsten filament to 118mA per watt for the thoriated filament used in the 1kW. radiotron U.V. 851. Several power valves with X-L filaments are then described with photographic illustrations of constructional details and curves of their characteristics, while the improvements in design rendered

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possible by the use of this filament are shown. The paper concludes with a table showing the operating constants and characteristics of five power valves with thoriated filaments and ranging from the 7.5 watts rating (U.V. 210) to the 1kW. of the U.V. 851 already mentioned.

R145.—INDUCTANCE AND CAPACITY. THE EFFECTS OF HARMONICS ON THEIR APPARENT VALUES. —P. Kemp (*Electrician*, 23rd Oct., 1925).

It is pointed out that if an E.M.F. of complex wave-form (*i.e.*, with harmonics) is applied to a simple inductance, the usual simple formula $E=2\pi fLI$ no longer holds. It is shown that if third, fifth, etc., harmonics are present the inductance of the circuit is apparently increased in the ratio

$$\sqrt{\frac{E_1^2 + E_3^2 + E_5^2 \cdots}{E_1^2 + \frac{E_3^2}{9} + \frac{E_5^2}{25} \cdots}}$$

This is worked out for harmonics of amplitude up to 25 per cent. of the fundamental amplitude, and shown both in table and curves.

Similarly, it is shown that the capacity is apparently increased in the ratio

$$\sqrt{\frac{E_1^2 + 9E_3^2 + 25E_5^2 \cdots}{E_1^2 + E_3^2 + E_5^2}}$$

The following table shows the higher values of increase for each case :—

Percentage Harmonic.	Percentage increase in apparent Inductance.			Percentage increase in apparent Capacity.		
	Third Har.	Fifth Har.	Seventh Har.	Third Har.	Fifth Har.	Seventh Har.
10	0.44	0.48	0.49	3.88	11.25	21.65
15	1.00	1.07	1.10	8.44	23.62	43.39
20	1.76	1.90	1.96	14.36	38.67	68.71
25	2.74	2.90	3.02	21.27	55.30	95.54

It is then shown that if calculations are based on the relative strength of harmonics present in a known *current* wave-form (instead of the form of the applied E.M.F.) the increases shown for inductance in the case of calculation on the E.M.F. wave-form are now applicable to capacity, and *vice versa*.

R200.—MEASUREMENTS AND STANDARDS.

R271.—NOUVELLE CONTRIBUTION A L'ETUDE DE LA PROPAGATION DES ONDES.—M. Lardry (*Onde Elec.*, Oct., 1925).

A continuation of the paper in *Onde Electrique* of Sept., 1925 (abstract in E.W. & W.E., Nov., 1925).

The author's measurements were continued on 50 metre stations, including the S.S. *Jacques Cartier*, on a voyage from Havre to the Gulf of Mexico and back. Curves are given of the readings taken on different stations. These show general similarity to the previous results on 450 and 115 metres. Measurements were also made on emissions of 48 and 50 metres sent out simultaneously from the same station. The results are similar as regards the mode of variation, but the 48-metre curve is two or three hours ahead of the 50-metre curve in details of variation.

The results are summed up as showing two distinct phenomena, (1) rapid fluctuations sometimes cutting signals down to unintelligibility; (2) longer period variations with a daily maximum and minimum, which the author compares to a tidal effect.

R300.—APPARATUS AND EQUIPMENT.

R342.6—SELECTIVE AMPLIFIERS.—P. K. Turner (E.W. & W.E., Oct., 1925).

The paper gives detailed consideration to the fundamentals of design of one or more stages of H.F. amplification to give a correct degree of selectivity. The familiar tuned anode circuit is illustrated and reduced to "equivalent circuit form." Symbols are assigned to the chief relationships of the circuit, and their general effect considered. The following curves are given to assist in the choice of circuit constants for any particular design, (*a*) efficiency against tune (*i.e.*, resonance curves) for different values of the ratio of anode resistance to coil reactance, (*b*) efficiency against this ratio for stages from 1 to 6, (*c*) efficiency against tune for stages from 1 to 6, (*d*) efficiency against frequency and/or wave-length for different values of a steady modulating frequency, (*e*) efficiency against ratio of anode resistance to coil reactance for 1, 2 or 3 stages and for different values of tuning ratio, (*f*) capacity against frequency and/or wave-length for different values of anode resistance. The use of the curves as aids in design are neatly summarised, while two appendices give details of the formulæ involved in the curves.

R342.6—A TRUE CASCADE R.F. AMPLIFIER.—Dr. L. M. Hull (*Q.S.T.*, Oct., 1925).

The author considers the question of obtaining a true cascade effect at radio frequencies, *i.e.*, a number, *n*, of stable stages, each yielding a voltage gain of *A*, so that the overall voltage gain is A^n. A brief description is given of such an amplifier (for about 400 metres), developed at the Radio Frequency Laboratories, Boonton, N.J. Each stage is copper-shielded, and casual reactions minimised. Specifically introduced reaction between the anode and grid circuits of *one* particular wave—the second in the cascade was actually used—was found not to be detrimental to true cascading, but two such reactions actually led to a net loss. Photographs and a circuit diagram are given of an amplifier to this pattern, four stages of H.F. amplification being followed by three audio stages.

R360.—SHORT WAVE RECEIVERS.—R. R. Batcher (*Q.S.T.*, Oct., 1925).

The author gives some notes on the design of parts for a short-wave receiver, devoting special attention to the coils and their sources of loss. A graph is given for the calculation of inductance, with a nomogram for inductance capacity and wave-length or frequency. Illustrations and a circuit diagram of the Grebe C.R.-17 short-wave receiver are given. The aerial is joined to the tuner through a small fixed condenser of 5$\mu\mu$F.

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Rectification occurs at the first grid, followed by an L.F. stage. Reaction (from the first anode to the aerial) is controlled by a 1 000$\mu\mu$F condenser shunted by a resistance of 25 000O joined in series between the H.T. + and the reacting coil.

R384.1. — PRESENTATION D'UN ONDEMÈTRE HETERODYNE.—E. Fromy (*Onde Elec.*, Oct., 1925).

It is pointed out that in an ordinary oscillating valve circuit, variation of operating conditions, especially of the L.T. and H.T. voltages, cause sufficient variation in frequency to render the arrangement unreliable as a wavemeter. These effects are shown to be due in the greater part to changes of phase in the different circuits. This can

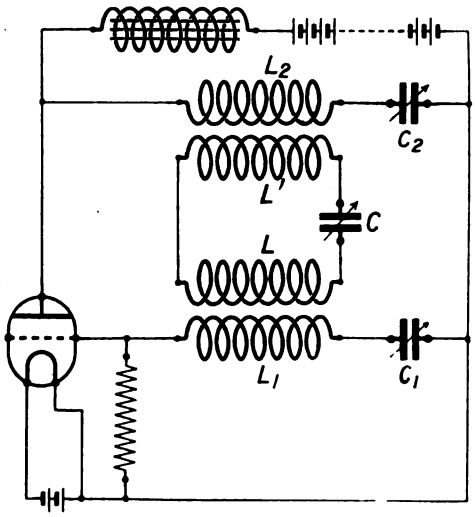

Fig. 1.

be overcome by the arrangement shown in Fig. 1 (redrawn from Fig. 2 of the paper). L_1 and L_2 have no mutual coupling, and the condensers C_1 and C_2 should be the order of C. Oscillations of very constant frequency can then be obtained in the $L\,L^1\,C$ circuit, a curve experimentally obtained showing a variation of less than 1 in 100 000 over a wide range of working voltages. Differences in interelectrode capacities prevent a fixed calibration allowing for changes of valve, but it is pointed out that this can be overcome by a very small variable condenser from anode to grid, readjusted to maintain a constant total capacity.

R386.—FILTERS: A SUPPLEMENTARY NOTE.—P. K. Turner (E.W. & W.E., Oct., 1925).

A supplement to the author's paper on "Filters" in E.W. & W.E. of August, 1925. Band Pass and Band Stop Filters are illustrated, and the expression for each given. Distinction is drawn between "width of band" and "sharpness of cut off," and the factors governing the former are considered.

R388.—DISTORTION IN WIRELESS TELEPHONY AND RELATED APPLICATIONS OF THE CATHODE RAY OSCILLOGRAPH.

See abstract under R135.

R600.—STATION EQUIPMENT, ETC.

R616.5.—BIRMINGHAM BROADCASTING STATION.—E. M. Deloraine (*Electrician*, 9th and 16th Oct., 1925).

The whole of the first article is devoted to theoretical considerations of the conditions to be fulfilled at transmitter and receiver for the best reproduction. The requirements of the human ear are first considered and illustrated graphically, as are the frequencies characteristics of speech as regards both energy and importance for intelligibility and the sound spectra of various musical tones from voice, piano, violin, clarinet and organ. The author discusses the possibility of arranging that the wireless transmitter should, over all, discriminate against low frequencies, leaving the receiver to discriminate against the higher audible frequencies, to secure a final balance in reproduction, but decides that the best system is one where the various frequencies are given their normal weight in the spectrum of sound energy. The second article considers the loudness of sound and range of variation to be transmitted and reproduced, and shows the necessity for a certain amount of control of level, *i.e.*, modulation amplification at the transmitter. The equipment of the new Birmingham Station is then described. A graph shows the frequency characteristics of (*a*) the carbon microphone, (*b*) the amplifiers and (*c*) the overall transmitter. Photographs are given of the speech input equipment, the radio transmitter panel, and microphone. Carbon and electrostatic microphones are both installed, three stages of amplification being used with the former and five with the latter. The transmitter is designed to deliver 1kW of unmodulated high frequency energy to the aerial.

Amateur Work in Egypt.

A FEW weeks ago the "Union of Greek Wireless Amateurs of Egypt" was formed, with headquarters in Alexandria and a membership of thirty.

At an electoral meeting Mr. L. P. Sclaoounos, who has been known to us for some time as an amateur, was elected President of the Union, and Mr. E. Brouzos and Dr. Glyki were appointed Secretary and Cashier respectively.

A laboratory has already been equipped and a high-power receiver installed, while permission is awaited from The Egyptian Government to erect a low-power transmitter. In addition, frequent lectures are given by the President.

We are confident that our readers will wish this new body every success and will be glad to co-operate with its members as much as possible. The address of the laboratory and offices is: Memphis Street, 24 (Camp de César), Alexandria, Egypt.

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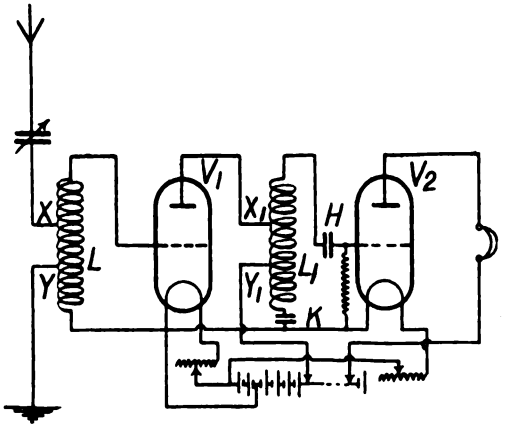
(The following notes are based on information supplied by Mr. Eric Potter, Patent Agent, Lonsdale Chambers, 27, Chancery Lane, W.C.2.) **[R008**

AN INTERVALVE COUPLING.

(Application date, 13th March, 1924. No. 235,312.)

An intervalve coupling in the form of a step-up transformer is described by K. D. Rogers and G. V. Dowding in the above British Patent. The invention is very simple in its nature, and lies in providing a step-up transformer of the auto-coupled variety.



This consists of a coil L provided with tappings at X and Y. The portions between one end of the coil and X and the other end of the coil and Y are identical and the points X and Y are connected with the aerial and earth respectively, while the outer ends of the coil are connected between the grid and the filament of the first valve, $V1$. A similar device is used to couple the amplifier valve to the detector valve $V2$. In this case the tapping points X_1 and Y_1 are connected respectively to the anode and the high tension battery, and one of the outer ends of the coil is connected to the grid, through the condenser H, while the other is taken to a small condenser K, which serves to isolate the high tension voltage from the filament. It will be noticed that neither the primary nor the secondary of the intervalve coupling is shown tuned. The device is presumably semi-aperiodic.

DULL EMITTER FILAMENTS.

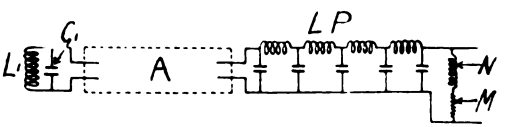
(Application date, 26th March, 1924. No. 236,615.)

A rather interesting method of manufacturing dull emitter filaments is described by E. Y. Robinson in the above British patent. It is pointed out in the specification that the coating used for dull emitter filaments is more easily applied to platinum and iridium alloys. Unfortunately alloys of this nature are not altogether satisfactory, as the tensile strength is not sufficiently great to enable them easily to be stretched between filament supports. According to the invention a core of tungsten or molybdenum wire, coated with platinum, is used. The coating may be deposited electrolytically, or in the form of platinum black, using a 3 per cent. solution of platinum chloride containing a trace of lead acetate. When the platinum has been deposited, the composite base is coated with the usual oxides in any convenient manner, such as mixing the oxides with wax or resin and burning off the carrier by heating the filament. The same method of construction is also mentioned in connection with equi-potential cathodes, in the form of coated cylinders, which are electrolytically or otherwise coated with platinum.

AN INTERESTING SYSTEM OF RECEPTION.

(Application date, 26th January, 1924. No. 233,024.)

A rather interesting system of reception is described in the above British Patent, which is granted to G. M. Wright. The object of the invention is to overcome the difficulty which is experienced in high speed signalling of the rounding off of the morse signals and the accentuation of the atmospherics. Briefly the idea consists in passing rectified currents due to incoming signals through a low pass filter and then through two impedances.



One impedance is such that the E.M.F. produced in it is proportional to the amplitude of the current giving rise to its E.M.F., while the other is such that the E.M.F. produced is at all instants proportional to the rate of change of the amplitude of the current. A recording device of some description is connected to the output of this arrangement, so that it is operated by the algebraic sum of the two E.M.F.s produced across the two

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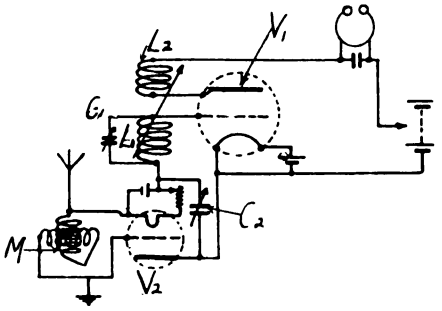
impedances. The arrangement is shown schematically in the accompanying illustration. The input circuit consists of an ordinary tuned circuit $L1$, $C1$ of exceedingly low damping. This is connected to an amplifier A, the output of which is connected to a low pass filter LP, comprising the usual arrangement of series inductances and shunt capacities. The two impedances N and M are connected to the output of the low pass filter. The impedance M is an ohmic resistance, in which the voltage produced is proportional to the current amplitude giving rise to the E.M.F., while the other is an inductance having substantially no ohmic resistance, in which the potential produced is at all instants proportional to the rate of change of the amplitude of the current. The recording device, of course, is simply connected across the two impedances. If it is assumed that damping of the input circuit $L1$, $C1$ is such that frequencies of 100 cycles on either side of the tuned point are very much reduced, it will be seen that morse signals received at the rate of perhaps 30 words a minute would be very much rounded off, a "hanging-on" being produced. Now the square modulation required in morse signals is given in the receiver by the combination of the interference tones produced by the rectifier. When the side frequencies are reduced, the correct blending of the tones to get the original modulation cannot occur, with the result that the signals are rounded. But it can be shown that by passing the mixture of interference tones through impedance of the type indicated in the diagram, the original square modulation effect will be reconstructed. It is further claimed that greater ease in reception is obtained for the following reason: If it is supposed that the low pass filter cuts off at 150 cycles, harmonics after rectification of the interference tones comprising the morse modulation will have frequencies greater than this figure, and will be heavily attenuated by the filter and may be neglected. The inverse of this, of course, is true.

A NOVEL SQUEGGER CIRCUIT.

(*Application date*, 11*th March*, 1924. *No.* 238,261.)

A rather novel squegger circuit is described by J. Robinson and T. H. Kinman in the above British Patent, one arrangement of which is shown in the accompanying illustration. The squegger

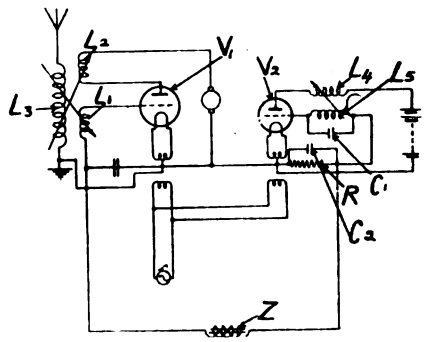


circuit, it will no doubt be remembered, consists in causing a valve to oscillate at a radio frequency and introducing into the grid circuit a resistance and a capacity, the time constant of which is adjusted so that it interrupts the production of continuous oscillations, thereby causing an audible note in the telephones. The incoming signals are caused to vary the time constant of the squegger device, thereby altering the resulting note. The novelty of the invention lies in replacing the fixed or variable resistance by means of the filament-anode impedance of a valve. Such an arrangement is shown in the accompanying illustration, in which it will be seen that the valve is caused to generate oscillations by the coupling between the grid circuit, $L1$, $C1$, and an anode coil $L2$. The resistance-capacity combination of the squegger device comprises a capacity $C2$ and the filament-anode impedance of the valve $V2$. In the normal arrangement the aerial circuit is connected in shunt with the grid circuit of the valve oscillator, but in the embodiment shown in the illustration a very much greater effect is obtained by connecting the aerial circuit between the grid and filament of the valve $V2$. Thus it will be seen that the aerial circuit is tuned by a variometer M which is connected between the grid and filament of the valve $V2$. Several other modifications are shown in the specification in which the squegger frequency is made supersonic, and also in which a reflex action is obtained. In this case the valve $V2$ is used to amplify the low frequency beat change from the anode circuit of the valve $V1$, the telephones, of course, being included in the anode circuit of the valve $V2$.

A GRID BIAS SCHEME.

(*Application date*, 11*th June*, 1924. *No.* 239,299.)

A method of obtaining grid bias for a valve oscillator is described in the above British Patent



by E. Y. Robinson and Metropolitan-Vickers Company, Limited. Briefly the invention consists in causing an auxiliary valve to generate oscillations either at radio or audible frequency, rectifying the oscillations so produced, obtaining a potential drop across the resistance in the circuits associated with the auxiliary oscillator, and applying this potential drop to the grid of the main oscillator. One simple arrangement is shown in the accompanying illustration, in which it will be seen that the valve V_1 generates radio frequency oscillations in the normal way, *i.e.*, by the coupling between the coils L_1 and L_2. Each in turn is shown coupled to the aerial circuit L_3. The

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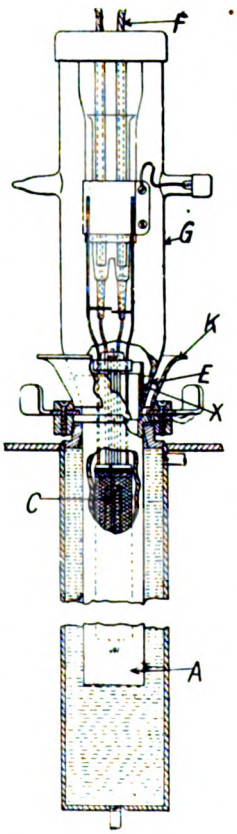
auxiliary valve $V2$ is also arranged to produce oscillations by virtue of the coupling between an anode coil $L4$ and a tuned grid circuit $L5$, $C1$. The grid circuit of this valve also contains a resistance R which is shunted by a capacity $C2$. The lower end of the grid coil of the main oscillator is not taken directly to the filament, but to the high potential end of the resistance R, thereby obtaining a steady negative potential. To prevent any interaction between the two valves a choke Z is included in this lead. The rest of the circuit is quite normal, alternating current being used for heating the filament, a generator being used for obtaining the high tension supply to the main oscillator, and a small battery for the local oscillator. The object of the scheme, of course, is to eliminate the usual high voltage and rather bulky grid battery which is normally employed.

A PROTECTED WATER-COOLED VALVE.

(*Convention date, U.S.A., 13th November, 1923. No. 224,906.*)

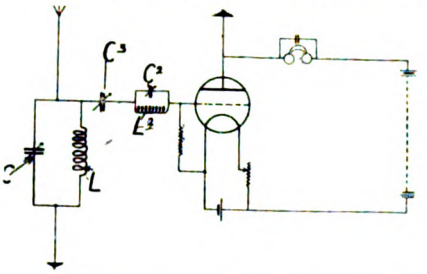
A form of protective construction for a water cooled valve is described in British Patent No. 224,906 by The British Thomson-Houston Company, Limited and H. J. Nolte. It is pointed out in the specification that arc discharges are liable to occur in high power valves, and very frequently the seal breaks down. The construction, which is shown in the accompanying illustration, is designed to overcome this difficulty. It will be seen that the valve is of the normal water-cooled anode variety, in which the anode A consists of a metal tube sealed to a glass stem G. The filament leads are shown at P and grid at C. The anode is sealed to the glass stem by means of an extension E, consisting of a copper coated and nickel-iron alloy having substantially the same expansion coefficient as that of glass. This seal is shielded by means of the extension of the anode X and the conical shaped portion K, which is extended to the glass tube. Thus it will be seen that the seal is completely between the portions X and K, with the result that all electrostatic stresses or actual arc discharges are eliminated, thereby preventing the tube from breaking down.



A RECEIVING SYSTEM.

(*Application date, 8th May, 1924. No. 238,003.*)

The accompanying diagram illustrates a form of receiver which is claimed by M. M. Melinsky in British Patent No. 238,003. It is stated in the specification that the arrangement produces an extremely sensitive and selective circuit, and a comparative freedom from undesirable noises such as atmospherics. We fail to see, however, how the system shown in the diagram can lessen the effect of atmospherics to any material extent.



Increased selectivity is, however, obviously obtained. Briefly the invention consists in using an ordinary aerial circuit L, C, including another tuned circuit in series with the grid lead and earthing the anode of the valve instead of the filament. Thus in the accompanying illustration it will be seen that between the output of the aerial and the grid a tuned circuit $L2$, $C2$ is included, a third condenser $C3$ of the order of $0.001\mu F$ being included. The anode is earthed at E. The novelty of the scheme obviously lies in the combination of these ideas, each of which, of course, is not new in itself. Several modifications of the idea are shown in the specification, but a 2-valve arrangement is not altogether clear to us. The anode of the first valve is coupled to the grid of the second through another series circuit similar to $L3$, $L2$, $C2$, but the anode of the second valve and the end of the tuned anode circuit of the first valve are both earthed, and the telephones are included in the common high tension lead. This arrangement obviously introduces a new feature into the scheme, whereas in another 2-valve arrangement, which is shown for low frequency work, the telephones are shown connected in the normal manner.

AN INTERESTING HIGH POWER VALVE.

(*Application date, 12th April, 1924. No. 236,992.*)

A high power valve with a rather unusual cathode is described by P. D. Tyers in the above British Patent. The valve is of the equi-potential type, the novelty of the invention lying in the construction of and method of heating the cathode. The accompanying illustration shows one form of the construction. The cathode consists of a cylinder C provided with an extension tube E, which is bent backwards at N and sealed at S to the walls W of the discharge chamber. In other words, the cathode, or rather an extension of it, forms a re-entrant tube. The cathode is heated by a heater element H, which is fixed to a support P which also carries cross-members X supporting

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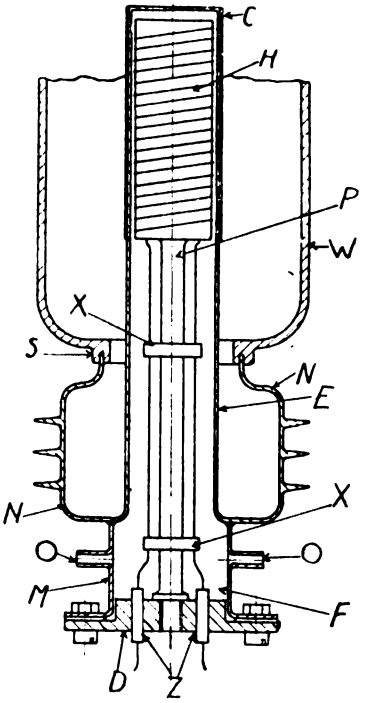
the leads from the heater. The end of the re-entrant tube is closed in by a "heater chamber" *F*, which simply comprises walls *M* closed by a plug *D*. The leads from the heater pass through

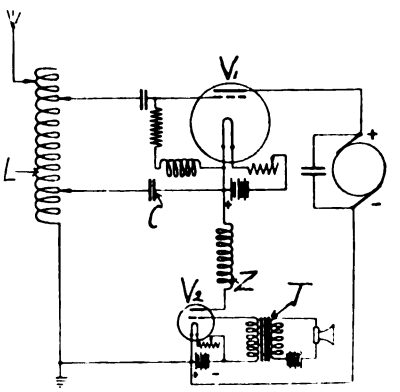


the plug at *Z*. The seal *S* between the re-entrant tube and the walls of the discharge chamber is an ordinary type of valve wall, and is intended to work at high vacuum. The seal *Z* through which the heater wires pass is a low vacuum seal. The valve is exhausted in the normal manner, and the cathode is heated by passing the current through the heater element. Owing to the boundary of the discharge chamber comprising the heater chamber, hydrogen and other similar gases in the atmosphere might pass through the heated metal, thus lowering the vacuum in the discharge chamber. In order to overcome this difficulty the space between the heater element and the plug is maintained at a low vacuum. The plug *P* is simply screwed on to the base of the walls *M* with an ordinary gasket. Outlets *O* are provided for producing a low vacuum, such as can be obtained from a small oil pump. It is claimed that the advantage of this type of construction enables a valve to be produced having an exceedingly long life owing to the very large active emission area of the cathode. It will further be seen that should the heater coil burn out, it can instantly be removed by unscrewing the plug and withdrawing it from the cathode tube. It is further pointed out in the specification that the valves allows a very rigid type of construction, in which the grid, for example, can be placed very near to the cathode, while, in addition, alternating current can be used for energising the heater coil; also there is no necessity to make a high current vacuum seal, the heater walls merely being of the ordinary low vacuum type. The cathods, of course, is coated, in order to increase the emission.

A SERIES MODULATION SYSTEM.

(*Application date, 18th June,* 1924. *No.* 239,309.)

A series modulation system is described in the above British Patent Specification, which is granted to G. W. Hale and Radio Engineering Company, Limited. The modulation system shown is of the type in which the anode-filament impedance of a valve is connected in series with some part of the oscillation circuit, and is varied by impressing speech voltages between the grid and the filament, thus modulating the output. The circuit shown in the accompanying illustration is comparable with several modifications described in the specification. We think, however, there must be some error in this circuit, as we fail to see exactly how the valve oscillates, since the anode circuit contains nothing other other than the voltage directly between the anode and earth, although in the specification it is stated that the anode is connected to the main aerial inductance *L*. Assuming, however, that the valve would generate oscillations, it will be seen that the filament is connected across part of the aerial inductance through a condenser *C*, and also across part of it, *i.e.*, through earth to a valve *V*2. A high frequency choke *Z* is included between the filament of the valve *V*1 and the anode of the valve *V*2. The filament of the valve *V*2 is thus connected to earth and also to the negative side of the high tension supply. A modulation transformer *T* is connected between the grid and the filament of the valve *V*2. The speech voltages impressed upon these vary its internal impedance, and alter the resistance path between the filament of the valve *V*1 and earth, thus modulating the output. Another modification



of the invention shows a similar arrangement in which the filament of the valve *V*1 is heated by passing the current through a choke and through part of the aerial inductance. The modulation valve *V*2 is then connected as before in series with the high tension supply. There appears to be very little difference between this arrangement and the more normal one of simply including a modulator valve in series with the low potential side of the high tension supply. This arrangement, of course, was in use about 1921 or 1922.

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